 Module 3: Waves and thermodynamics

Year 11 science 2018

Duration: 6 hours

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Description of unit

Students use inquiry to investigate the relationships of temperature, thermal energy and particle motion through practical activities, internet resources and computer simulations. This knowledge is applied to calculate changes in thermal energy due to heat changes measured by temperature.

This unit has been designed to be uses within a flipped classroom context, maximising students chances to develop their knowledge and working scientifically using investigations within the time period available. A wide range of investigations have been included to allow differentiation and should be selected based on student ability.

Inquiry questions

How are temperature, thermal energy and particle motion related?

Outcomes

Working scientifically skills

* PH11-1 develops and evaluates questions and hypotheses for scientific investigation
* PH11-2 Designs and evaluates investigations in order to obtain primary and secondary data and information
* PH11-3 Conducts investigations to collect valid and reliable primary and secondary data and information
* PH11-4 Selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media
* PH11-5 analyses and evaluates primary and secondary data and information
* PH11-6 solves scientific problems using primary and secondary data, critical thinking skills and scientific processes
* PH11-7 communicates scientific understanding using suitable language and terminology for a specific audience or purpose

While all Working Scientifically outcomes have been presented in this sample unit of work, teacher judgement should be used about which skill descriptors students will be working towards and engaging with.

Knowledge and understanding

* PH11-11 explains and quantitatively analyses electric fields, circuitry and thermodynamic principles

Assessment

* Report of practical activities and simulations

Flipped learning

The following sample unit of work contains elements of flipped learning. Flipped learning is an instructional strategy (type of blended learning) that delivers instructional content outside of the classroom. Students gain exposure to new material outside of class such as online learning, reading tasks, lecture videos, podcasts, and so on. Corresponding lessons are used to collate and assimilate that knowledge through problem solving, discussion, or other strategies.

The key of flipped learning is to engage students in active learning where there is a greater focus on student’s application of conceptual knowledge rather than rote learning or factual recall. The following diagram depicts the learning opportunities if the flipped classroom which can be used when creating lessons (adapted from Gerstein).



| Outcomes/content | Teaching and learning | Evidence of learning |
| --- | --- | --- |
| * explain the relationship between the temperature of an object and the kinetic energy of the particles within it (ACSPH018)
 | Flipped content [students to complete activities before lesson]* [How temperature and thermal energy related](http://study.com/academy/lesson/what-is-thermal-energy-definition-examples.html)? http://study.com/academy/lesson/what-is-thermal-energy-definition-examples.html
* [States of matter: basics](https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_en.html) https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics\_en.html
* [Particle theory of matter](https://sciencesource.pearsoncanada.ca/quizzes/quiz_07_2b3Xn9.htm) [sciencesource.pearsoncanada.ca/quizzes/quiz](https://sciencesource.pearsoncanada.ca/quizzes/quiz_07_2b3Xn9.htm)

**In class**Pretest: [Particle model: test](http://www.bbc.co.uk/bitesize/quiz/q55085057) http://www.bbc.co.uk/bitesize/quiz/q55085057Students explore states of matter (refresher) [Simulation](https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_en.html) https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics\_en.htmlStudents engage with a quick experiment – students dib cotton wool in methylated spirits or rubbing alcohol. Ask students what they experience and why? Scope for class discussion. Predict Observe Explain: students investigate heating different amounts of water and measuring temperature. An example is to heat 50mL and 100mL of water for the same amount of time and measure the temperature. Record observations and make inferences that can be explained using the particle model and clarify difference between heat and temperature.Flipped content [students to complete activities before lesson]View/interpret/explain how the motion of particles relate to temperature. This should be assigned to students to be completed prior to the lesson. Use the simulations below to explain the changes in the particles as heat is applied to solids, liquids and gases. * [States of matter](https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_en.html) https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics\_en.html
* Heating and cooling affects the [kinetic energy of matter](https://phet.colorado.edu/en/simulation/energy-forms-and-changes) [phet.colorado.edu/en/simulation/energy-forms-and-changes](https://phet.colorado.edu/en/simulation/energy-forms-and-changes)

**In class**Students can explore a series of investigations to investigate temperature and kinetic energy of objects. Teachers can set which investigations to do or allow students to engage in a range by setting up stations (if feasible, noting potential risks and hazards). * Balloon in a freezer
* Heating different amounts of matter
* Liquid nitrogen to freeze objects
* Dry ice experiments
* Ice in water

Students should explain and elaborate how the particle model explains the observations for the experiments in the explore section. Students work in groups to come up with definitions of energy and temperature. Students fill in a cartoon strip or similar illustrating particle motion in the water in both volumes. Students should use the question ‘what is happening in the thermometer?’ as a driving question. Teacher can choose other questions to be framed.  | * Students define thermal energy, heat and temperature.
* Students recognise the relationship AND distinguish between thermal energy and temperature the motion of particles greater for less volume.
* Students recognise and communicate the relationship between heat and temperature.
* Student recognise that heat is absorbed to increase kinetic energy of evaporation.
* Students elaborate on the particle model.
 |
| * explain the concept of thermal equilibrium (ACSPH022)
* investigate energy transfer by the process of:
	+ conduction
	+ convection
	+ radiation (ACSPH016)
 | Flipped content [students to complete activities before lesson]* [How does heat travel](http://coolcosmos.ipac.caltech.edu/cosmic_classroom/light_lessons/thermal/transfer.html) http://coolcosmos.ipac.caltech.edu/cosmic\_classroom/light\_lessons/thermal/transfer.html
* Students present the information in their own words.

**In class**Student can engage understanding thermal equilibrium Use three beakers of water. Put iced water in the bowl on the left, water hot enough for a bath in the bowl on the right, and room temperature water in the one in the middle. Get students to place a hand in each of the two outer bowls, leave them there for a few minutes, then place both hands in the middle bowl. Students record and discuss their observations in terms of temperature and heat flow.Students predict and feel the temperatures of various objects in the classroom. [Tables, sinks, walls, windows, metal sinks, concrete, brick, paper towels, etc]. Students make observations and qualitative/estimated quantitative of temperature. Measuring temperature of different objects in the same area using thermocouple/temperature probe and compare the measured temperatures with the predicted temperatures. Students work in groups attempt to explain their observations.Flipped content [students to complete activities before lesson]* Students complete a table writing their own definitions for conduction, convection and radiation and a real life example of each, without using research technologies.
* Students watch [misconceptions about heat](https://www.youtube.com/watch?v=hNGJ0WHXMyE) https://www.youtube.com/watch?v=hNGJ0WHXMyE

**In class**Teacher displays a picture of an igloo made from ice and asks students, “how do igloos keep people warm?” Students write their ideas after discussing with a partner.[Conduction Convection Radiation:](http://oceanmotion.org/) http://oceanmotion.org/* A model in a cup: A cup of hot water can be used as a model that illustrates some facts about convection currents. This can be explored by students using a beaker of water which can be heated with a Bunsen burner. A grain of rice can be added to visualise.
* Students can attempt another investigation by filling two separate cups (without a lip, e.g. gas jar) with hot water and cold water. Hot water can be coloured red and cold water coloured blue for visual effect. Students can observe how particles travel differently in water of differing temperatures.
* Conduction investigation: qualitative investigation, do different metals feel colder? Students can rank metals and discuss responses. Verification by checking with a digital temperature probe.

[Thermal conductivity of metals](http://www.engineeringtoolbox.com/thermal-conductivity-metals-d_858.html) http://www.engineeringtoolbox.com/thermal-conductivity-metals-d\_858.htmlStudents use thermal conductivity data to rank them. Students attempt to make generalisations and find trends in data.[Convection current investigation](http://www.ucar.edu/learn/1_1_2_7t.htm) http://www.ucar.edu/learn/1\_1\_2\_7t.htmStudents explain how convection currents influence atmospheric processes, including high and low-pressure systems, some weather phenomena, etc. Students research and investigate Newton’s Law of Cooling. Students create a poster/infographic/other presentation medium to convey information. [Teacher notes](http://electron6.phys.utk.edu/101/CH7/Heat%20Flow.htm) if needed http://electron6.phys.utk.edu/101/CH7/Heat%20Flow.htmFlipped content [students to complete activities before lesson]Choose from one of the following* Ocean lag of temperature to air
* El Niño
* thermosphere

**In class**Students investigate Peltier plates/thermoelectric generators. Teachers to access inquiry based lessons and activities for use with students. [Ausgrid thermoelectric generators](https://learnelectricity.ausgrid.com.au/-/media/Microsites/HighSchoolEducation/Thermoelctric-Generator-lessons/Thermoelectric-Generator-inquirybased-lessons-and-activitie_Ausgrid_HSR-s.pdf?utm_source=Direct%20Mail&utm_medium=PDF&utm_content=ThermoElectric%20Lessons&utm_campaign=Energy%20Efficiency%20Lesson%20PDFS&la=en&hash=31B64B8CD8E353E43DA9B0E34CECEA4C69357C42)Experiments* Students explore conduction by investigating ice cubes on different materials. [Melting ice](https://www.nuffieldfoundation.org/sites/default/files/files/Melting%20ice%20-%20merged%20PDF.pdf) https://www.nuffieldfoundation.org/sites/default/files/files/Melting%20ice%20-%20merged%20PDF.pdf
* [Sankey diagrams](http://www.bbc.co.uk/schools/gcsebitesize/science/aqa/energyefficiency/energytransfersrev3.shtml) http://www.bbc.co.uk/schools/gcsebitesize/science/aqa/energyefficiency/energytransfersrev3.shtml
* [conduction Ice block](https://www.youtube.com/watch?v=XBu0vXzmZDo) https://www.youtube.com/watch?v=XBu0vXzmZDo
* [Peltier plates](https://www.youtube.com/watch?v=RC16MwzFq8A) https://www.youtube.com/watch?v=RC16MwzFq8A
* Student plan and conduct an investigation to attempt to measure temperature of liquids at different parts of convection current
* Student explore rheoscopic fluid and view currents flowing in a liquid. This can be either bought or made in class (follow safe working procedures, including using a respirator and gloves) using distilled water, food colouring and powdered mica. The solution can be made in a beaker and heated to view convection currents or place in a small bottle to view currents flowing.
 | * Students explain heat transfer.
* Students identify the natural direction of heat flow.
* Student explain energy transfer by conduction, convection and radiation using real world situations.
* Explain the cooling curves obtained using the concept of thermal equilibrium.
* Survey and explanation of misconceptions – heat transfer, temperature of objects.
 |
| * model and predict quantitatively energy transfer from hot objects by the process of thermal conductivity
 | Flipped content [students to complete activities before lesson]Students watch the [video](https://www.khanacademy.org/science/physics/thermodynamics/specific-heat-and-heat-transfer/v/intuition-behind-formula-for-thermal-conductivity) and identify and describe the components of the equation that can be used to model and predict energy transfer through thermal conductivity. https://www.khanacademy.org/science/physics/thermodynamics/specific-heat-and-heat-transfer/v/intuition-behind-formula-for-thermal-conductivity**In class**Predict Observe Explain: mixing different volumes of water at different temperatures.Students research examples of infrared images and videos to discuss how energy is transferred. Students attempt to make a conclusive statement about the transfer of energy from hot objects.Students explain [thermal equilibrium](http://study.com/academy/lesson/thermal-equilibrium-definition-formula-example.html) in their own words using [stimulus](http://study.com/academy/lesson/thermal-equilibrium-definition-formula-example.html) http://study.com/academy/lesson/thermal-equilibrium-definition-formula-example.html. Students can create an infographic or small poster.Students model energy transfer by discussing heat transfer principles of coffee cups. Students investigate which coffee cup is the best: ceramic, glass, paper cup, styrofoam. Students may choose to use heat transfer equation ΔT=qR (where T: temperature, q: heat transfer rate, R: equivalent thermal resistance). An example can be found [here](https://prezi.com/iwto6j4zvzni/heat-transfer-principles-of-coffee-cups/) https://prezi.com/iwto6j4zvzni/heat-transfer-principles-of-coffee-cups/ | * Students present a model energy transfer by thermal conduction
* Students explain energy transfer.
* Students define the first law of thermodynamics.
 |
| * analyse the relationship between the change in temperature of an object and its specific heat capacity through the equation$Q=mc∆T$ (ACSPH020)
 | Teacher background: specific heat capacity and is defined as the amount of energy required to increase the temperature of 1 kg of the substance by 1 °C (or K). When heated, some materials increased in temperature more quickly than others.Student engage with different simulations to carry out specific heat capacity investigations.* [Specific heat capacity](http://employees.oneonta.edu/viningwj/sims/specific_heat_s.html) http://employees.oneonta.edu/viningwj/sims/specific\_heat\_s.html
* [Specific heat capacity](https://www.geogebra.org/m/P8Gj2RNF) (Geogebra) https://www.geogebra.org/m/P8Gj2RNF
* [Heat and thermodynamics](https://phet.colorado.edu/en/simulations/category/physics/heat-and-thermodynamics) https://phet.colorado.edu/en/simulations/category/physics/heat-and-thermodynamics https://phet.colorado.edu/en/simulation/legacy/energy-forms-and-changes
* Investigate the specific heat capacity of aluminium: a heated block of aluminium from the oven and placing it in an insulated cup of water. Measuring the masses of the water and the block and the initial temperatures of the water and the block as well as the final temperature of the water and the block, then the heat capacity can be determined.
* Design an investigation to compare the specific heat of various materials using this [simulation](http://employees.oneonta.edu/viningwj/sims/specific_heat_s.html) http://employees.oneonta.edu/viningwj/sims/specific\_heat\_s.html
* How does the ocean store energy over time? In this investigation students will explore the energy flow at the ocean’s surface using a simple computer model, Energy Flow Model, to track energy exchanges. Exploring this model will help students develop a better understanding of how the ocean’s surface responds to solar heating and how the ocean stores energy over time. [Energy Flow Model](http://www.oceanmotion.org/html/resources/upperlayer.htm) http://www.oceanmotion.org/html/resources/upperlayer.htm

Students work in groups to come up with a definition of specific heat capacity.Students solve problems of specific heat capacity of metals. | * Define specific heat capacity
* Solves problems using

$Q=mc∆T$ * Describe how heat flows from hot to cold.
* Explain that some materials hold and release more energy than others (specific heat).
 |
| * conduct an investigation to analyse qualitatively and quantitatively the latent heat involved in a change of state
 | Students hold a small block of ice in your initially dry hand and allow the ice to melt.  Take note of how cold the water produced feels compared to the unmelted ice. Does melted water feel colder than the ice or does it feel just as cold as the ice? Pose question: why are steam burns more severe than boiling water?Students conduct an investigation to explore latent heart. * [Heat of Fusion Steric Acid](http://wordpress.mrreid.org/2009/12/08/experiments-that-actually-work-latent-heat-of-fusion/) http://wordpress.mrreid.org/2009/12/08/experiments-that-actually-work-latent-heat-of-fusion/ Collect data to investigate the heat of fusion stearic acid or lauric acid when heated beyond its melting point and then cooled.
* [The Latent Heat of Fusion of Ice](http://tap.iop.org/energy/thermal_physics/file_40492.doc) http://tap.iop.org/energy/thermal\_physics/file\_40492.doc

Students construct graphs for investigations and analyse them to account for trends.Students discuss latent heat and how it can benefit modern applications.[How does temperature and thermal energy explain why more severe than a boiling water burn?](http://wordpress.mrreid.org/2012/09/27/specific-heat-latent-heat-and-scalds/) http://wordpress.mrreid.org/2012/09/27/specific-heat-latent-heat-and-scalds/ | * Students define latent heat and apply to real world situations
* Student can explain the data/graphs using the partial model
 |
| * apply the following relationships to solve problems and make quantitative predictions in a variety of situations:
	+ $Q=mc∆T $where c is the specific heat capacity of a substance
	+ $\frac{Q}{t}$=$\frac{kA∆T}{d}$ where k is the thermal conductivity of a material
 | Students engage by conducting a practical whereby they heat an origami cup/paper boat/unwaxed paper cup filled with water. Students can heat this over a Bunsen burner (a Meker Bunsen burner works best or a gas stove). Instructions can be found [here](https://www.education.com/science-fair/article/boiling-water-paper-cup/) https://www.education.com/science-fair/article/boiling-water-paper-cup/. Students discuss why the water was able to heat in a paper vessel.Thermal conductivity* [Virtual Flash Lab](http://vlab.amrita.edu/?sub=1&brch=194&sim=801&cnt=1) on heat transfer by conduction. Students need to record data and apply formula $\frac{Q}{t}$=$\frac{kA∆T}{d}$ to find the thermal conductivity of a material by the two slabs guarded hot plate method. http://vlab.amrita.edu/?sub=1&brch=194&sim=801&cnt=1
* Use the [Energy2D](http://energy.concord.org/energy2d/conduction-test.html) to model quantitatively the impact of the different variables in rate of heat transfer equation, k, A, and d. Students can change the properties of the materials by right clicking or dragging. To change the distance, you will need to make the heat source draggable. http://energy.concord.org/energy2d/conduction-test.html

Identify symbols and units for equations. Students relate the equations to what has been learnt so far. Experiment$ Q=mc∆T$ investigation using different volumes of water. Groups of students can choose different volumes for example 100 mL, 200 mL, 500 mL, 1000 mL and collate results into one online graph. Students discuss trends, differences and come up with conclusions.Students explain specific heat capacity (metals and water). Students relate the significance of heat capacity of water in Earth systems.Apply $Q=mc∆T$ and $\frac{Q}{t}$=$\frac{kA∆T}{d}$in a variety of problems. Students apply the formulas to solve problems and make predictions based on variations of materials and their mass and size.* Problems on Energy Transfer Processes
	+ Which requires more energy, making soup or making toast? Explain
	+ What are the advantages of double glazed windows?
	+ When poor people are forced to sleep outdoors in cold weather they sometimes use newspapers for blankets. What good is this? Why?
	+ Why are loose fitting clothes more comfortable than tight fitting clothes in hot climates?
	+ How does a thermos flask keep food hot?
 | * Recognise Heat and kinetic energy relationship
* Explanation uses temperature thermal energy and particle motion in correct context.
* Solves problems using
	+ $Q=mc∆T$
	+ $\frac{Q}{t}$=$\frac{kA∆T}{d}$
 |

Resources:

* Institute of Physics: [Teaching Advanced Physics](http://tap.iop.org/energy/thermal/index.html): http://tap.iop.org/energy/thermal/index.html
* [Institute of Physics Practicals](http://www.practicalphysics.org/energy.html): http://www.practicalphysics.org/energy.html
* [twobitcircus.org](http://twobitcircus.org/wp-content/uploads/2017/03/HS-THERMO-PuttPutt-lesson-plans.pdf): http://twobitcircus.org/wp-content/uploads/2017/03/HS-THERMO-PuttPutt-lesson-plans.pdf
* [Hyperphysics](http://hyperphysics.phy-astr.gsu.edu/hbase/heacon.html): http://hyperphysics.phy-astr.gsu.edu/hbase/heacon.html
* [Khan Academy](https://www.khanacademy.org/science/physics/thermodynamics): https://www.khanacademy.org/science/physics/thermodynamics
* [Energy2d simulator](http://energy.concord.org/energy2d/index.html): http://energy.concord.org/energy2d/index.html
* [Energy efficiency project](https://concord.org/projects/engineering-energy-efficiency#curriculum): https://concord.org/projects/engineering-energy-efficiency#curriculum

Reflection and evaluation: