THE CURIOUS SCIENTIST AI

THERMODYNAMICS

A FOCUSED GUIDE FOR HSC STAGE 6 PHYSICS

EMERGENT MIND PRESS

Introduction

WELCOME TO HSC PHYSICS! You are about to embark upon an extraordinary journey, exploring the fundamental laws that govern our universe—from the smallest subatomic particles to the vast expanses of galaxies. Physics is a remarkable field of study that challenges our perceptions and sharpens our curiosity, imagination, and analytical skills. It enables us to comprehend the natural phenomena around us and equips us with the tools to solve complex problems in our ever-changing world.

This textbook is specifically tailored for advanced students following the NSW HSC curriculum. Our goal is to support your unique strengths, interests, and learning styles, and to provide a challenging yet accessible resource that prepares you thoroughly for your Higher School Certificate (HSC) Physics examinations.

How to Use This Textbook

The textbook is carefully structured to help you navigate through the course content effectively. It includes several features specifically designed to accommodate diverse learning styles and to encourage active engagement with Physics concepts.

Main Text

The main text systematically presents each topic within the HSC syllabus, clearly explaining the core concepts, theories, and laws of Physics. Throughout the chapters, explanations are supported by examples, diagrams, and step-by-step problem-solving demonstrations.

Margin Notes

Margin notes are provided alongside the main text, offering additional insights, clarifications, and historical context. These notes are intended to enrich your understanding and to spark curiosity. Margin notes may include:

- **Historical Insights:** Brief accounts of discoveries, biographies of influential physicists, and historical developments.
- **Concept Checks:** Short questions or reflections to test your understanding as you progress through a section.
- **Quick Tips:** Study strategies, memory aids, and helpful reminders to reinforce essential concepts.

Investigations and Activities

Physics is fundamentally an experimental science. Throughout this book, you will encounter investigations and hands-on activities designed to deepen your conceptual understanding and develop your skills in scientific inquiry. Each investigation clearly outlines objectives, required materials, safety considerations, and guided instructions.

Physics is best understood through direct experience and inquiry.

Worked Examples and Practice Problems

Worked examples illustrate step-by-step solutions to typical problems encountered in HSC examinations. Practice problems follow each section, allowing you to apply your knowledge and to build confidence in problem-solving techniques.

Chapter Summaries and Review Questions

At the conclusion of each chapter, summaries consolidate the key ideas and concepts discussed, while review questions and exam-style problems provide opportunities to revise and reflect upon your learning.

Overview of the NSW HSC Physics Course

The NSW HSC Physics syllabus comprises two distinct stages: the Year 11 (Preliminary) course and the Year 12 (HSC) course. Each stage encompasses specific modules, as outlined below.

Year 11 (Preliminary) Modules

In Year 11, you will build foundational knowledge and skills to prepare for the more advanced concepts studied in Year 12. The Preliminary course consists of four modules:

1. **Kinematics:** Discover how objects move, exploring displacement, velocity, acceleration, and motion graphs.
2. **Dynamics:** Investigate forces, Newton's laws of motion, and applications such as friction and projectile motion.

3. **Waves and Thermodynamics:** Explore wave phenomena, properties of sound and light, and the fundamental concepts of heat and temperature.
4. **Electricity and Magnetism:** Examine electrical circuits, magnetism, electromagnetic forces, and their real-world applications.

Year 12 (HSC) Modules

In Year 12, you will deepen your understanding, applying concepts from the Preliminary course to more complex scenarios, phenomena, and technologies. The HSC course consists of four modules:

1. **Advanced Mechanics:** Extend your knowledge of motion and forces, examining circular motion, projectile motion, and gravitational fields.
2. **Electromagnetism:** Delve deeper into magnetic fields, electromagnetic induction, electric motors, generators, and transformers.
3. **The Nature of Light:** Investigate the wave-particle duality of light, including interference, diffraction, and quantum concepts such as photons and photoelectric effects.
4. **From the Universe to the Atom:** Explore cosmology, astrophysics, nuclear physics, and the fundamental nature of matter, energy, and radiation.

How to Use This Textbook Effectively

Effective learning in Physics involves consistent engagement, focused practice, and strategic preparation. Consider the following recommendations to maximise your success in HSC Physics.

Study Tips

- **Active Engagement:** Regularly participate in class discussions, investigations, and collaborative activities. Physics requires active thinking and questioning.
- **Consistent Revision:** Regularly review concepts, formulas, and definitions. Frequent revision consolidates memory and enhances long-term retention.
- **Problem-Solving Practice:** Consistently attempt practice problems and past HSC exam questions to build strong problem-solving skills.
- **Use Margin Notes Wisely:** Margin notes offer concise and accessible insights. Use these notes as quick references for revision and to further explore areas of interest.

- **Adapt to Your Learning Style:** Recognise what works best for you—visual diagrams, hands-on experiments, verbal explanations, or written summaries—and adapt your study methods accordingly.

Navigation and Organisation

- **Table of Contents and Index:** Familiarise yourself with the structure of the textbook. Use the table of contents to plan your study schedule and the index to locate specific topics quickly.

- **Margin Space:** Utilise the generous margin space provided in this textbook to write notes, highlight important information, or pose questions for further exploration.

Preparation for HSC Examinations

- **Understanding the Syllabus:** Clearly understand the HSC Physics syllabus outcomes, content, and assessment criteria. Align your study and revision strategies accordingly.

- **Practice Examination Conditions:** Regularly practise completing exam-style questions under timed conditions to become familiar with examination scenarios.

- **Seek Feedback:** Regularly discuss your understanding and performance with teachers or peers. Constructive feedback is invaluable for identifying areas for improvement.

The Nature and Importance of Physics

Physics is not only a discipline of knowledge but a way of thinking. Physicists are inquisitive, critical, and creative individuals who use logic, experimentation, and mathematics to solve problems and understand the universe.

"Physics is about questioning, studying, probing nature. You probe, and if you're lucky, you get strange clues."—Lene Hau, Physicist

Physics reveals the underlying rules that govern our universe. It has led to transformative technological advancements—from electricity generation and medical imaging to spacecraft navigation and quantum computing. As you study Physics, you will develop skills in critical thinking, problem solving, mathematical reasoning, and experimental design, all of which are invaluable in diverse careers and fields of study.

Moreover, Physics fosters a deep appreciation of nature's elegance and complexity. It encourages curiosity, inspires innovation, and prompts us to ask profound questions about our place in the universe.

A Word of Encouragement

As you begin this exciting journey, remember that learning Physics is both challenging and rewarding. You may encounter concepts that initially seem complex or abstract—this is entirely normal. Persevere, embrace curiosity, and remain open to exploring ideas in diverse ways. Seek support and collaboration, and actively engage with the resources provided in this textbook.

By approaching your study of Physics with enthusiasm, curiosity, and determination, you will gain an invaluable understanding of the natural world and acquire skills that will serve you well throughout your life.

Welcome to HSC Physics. We look forward to exploring the wonders of physics with you!

Thermodynamics

This chapter delves into the principles of thermodynamics, exploring the fundamental relationship between heat, energy, and the behaviour of matter at the microscopic level. We will investigate how temperature relates to particle motion, how thermal energy is transferred, and the concepts governing energy transformations and equilibrium. Building on our understanding of energy transfer from waves, we now focus on the thermal domain.

Inquiry Questions:

- How are temperature, thermal energy, and particle motion related?
- How does energy transformation underpin the laws of thermodynamics? (Focus here on energy transfer mechanisms and quantification)
- What predicts and determines the direction and efficiency of energy transfer? (Focus here on equilibrium and heat capacity)

Syllabus Outcomes Covered: PH11-10, PH11/12-3, PH11/12-4, PH11/12-6, PH11/12-7

Temperature, Thermal Energy, and Particle Motion

Our understanding of heat and temperature is grounded in the **particle model of matter**, which describes substances as being composed of constantly moving particles (atoms or molecules). The energy associated with this motion is crucial to thermodynamics.

particle model of matter: Definition goes here

Key Concept: Temperature and Kinetic Energy

Temperature is a measure of the average kinetic energy of the particles within a substance. It reflects how vigorously, on average, the particles are moving (translating, vibrating, rotating). **Thermal energy**, on the other hand, represents the total internal energy of a substance due to the kinetic *and* potential energy of its particles. It depends not only on temperature but also on the mass and type of substance.

It's important to distinguish between temperature and thermal energy. A large body of water (like a swimming pool) at a lower temperature can contain significantly more thermal energy than a small cup of water at a higher temperature because it has vastly more particles, even if their average kinetic energy is lower.

Thermal energy: Definition goes here

Syllabus Ref: PH11-10 (ACSPH018)

Bloom's Level: Understand

Literacy Skills: Define temperature, Explain particle energy distribution, Relate kinetic energy to temperature.

Numeracy Skills: Interpret particle energy distributions graphically.

Video Resource: See 'media/particle$_m odel_t emperature.mp4'foravisualexplanatio$

Stop and Think

Consider a litre of water at 80°C and 10 litres of water at 20°C. Which has the higher temperature? Which contains more thermal energy? Explain your reasoning based on the particle model.

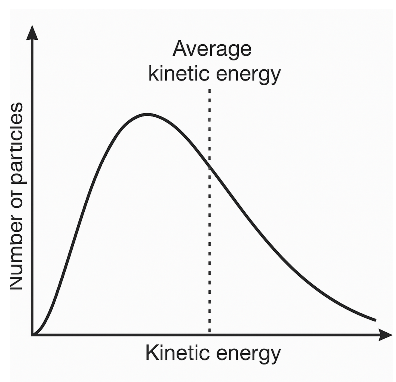

Figure 1: A typical distribution of kinetic energies among particles in a substance at a given temperature. Higher temperatures shift the average energy to the right and broaden the distribution.

*** Challenge:** Research the difference between translational, rotational, and vibrational kinetic energy for molecules. How do these contribute differently to the thermal energy of solids, liquids, and gases?

History: The connection between heat and particle motion was solidified by scientists like James Prescott Joule in the mid-19th century, challenging the earlier 'caloric' theory of heat as a fluid.

Thermal Equilibrium

When objects at different temperatures are brought into thermal contact, energy naturally flows from the hotter object to the colder one. This process continues until the objects reach a state of **thermal equilibrium**.

Key Concept: Thermal Equilibrium

Thermal equilibrium is the state reached when two or more objects in thermal contact cease to have any net transfer of thermal energy between them. At equilibrium, they are at the same temperature. This concept is fundamental to the **Zeroth Law of Thermodynamics**, which states that if two systems are each in thermal equilibrium with a third system, then they are in thermal equilibrium with each other.

Think about placing a thermometer in warm water. The thermometer's reading increases as thermal energy flows from the water to the thermometer. The reading stabilises when the thermometer reaches thermal equilibrium with the water – they are at the same temperature, and there is no further net energy transfer. Similarly, a hot drink left on a table will cool down until it reaches thermal equilibrium with the surrounding air.

Related HSC Question: HSC2020Q14b

thermal equilibrium: Definition goes here

Zeroth Law of Thermodynamics: Definition goes here

Syllabus Ref: PH11-10 (ACSPH022)

Bloom's Level: Analyse

Literacy Skills: Define thermal equilibrium, Explain energy transfer directions, Summarise Zeroth Law.

Numeracy Skills: Interpret equilibrium diagrams.

Demo Video: See 'media/thermal$_e quilibrium_d emo.mp4'forademonstration.$

Stop and Think

Why is the term 'net' transfer important when discussing thermal equilibrium? Do particles stop exchanging energy altogether?

Related HSC Question: HSC2019Q12a

Quantifying Heat Transfer: Specific Heat Capacity

Different substances require different amounts of thermal energy to change their temperature by the same amount. This property is quantified by the **specific heat capacity**.

Key Concept: Specific Heat Capacity (c)

Specific heat capacity (c) is the amount of thermal energy required to raise the temperature of one kilogram of a substance by one Kelvin (or one degree Celsius). Its unit is Joules per kilogram per Kelvin (J kg^{-1} K^{-1}) or Joules per kilogram per degree Celsius (J kg^{-1} °C^{-1}). The relationship between thermal energy transferred (Q), mass (m), specific heat capacity (c), and temperature change (ΔT) is given by:

$$Q = mc\Delta T \tag{1}$$

where $\Delta T = T_{final} - T_{initial}$. A positive Q indicates energy absorbed by the substance, while a negative Q indicates energy released.

Water has a very high specific heat capacity compared to many other substances. This means it takes a lot of energy to heat water up, and water releases a lot of energy when it cools down. This property is crucial for climate regulation (large bodies of water moderate temperature changes) and in biological systems.

Example:

How much thermal energy is required to heat 2.0 kg of water from 20°C to 80°C? (Use $c_{water} = 4186$ J kg^{-1} K^{-1})

Solution: Identify the known values: $m = 2.0$ kg $c = 4186$ J kg^{-1} K^{-1} $T_{initial} = 20$°C $T_{final} = 80$°C Calculate the temperature change: $\Delta T = T_{final} - T_{initial} = 80C - 20C = 60$°C (or 60 K) Apply the formula: $Q = mc\Delta T$ $Q = (2.0\,\text{kg}) \times (4186\,\text{J kg}^{-1}\,\text{K}^{-1}) \times (60\,\text{K})$ $Q = 502320$ J $Q \approx 5.0 \times 10^5$ J (or 500 kJ)

Therefore, approximately 500 kJ of thermal energy is required.

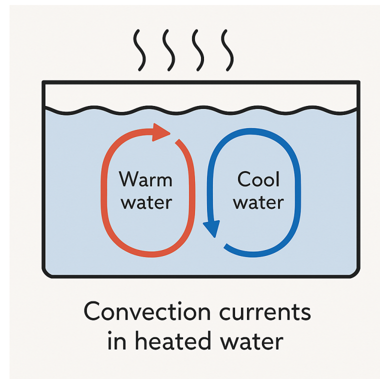

Figure 2: Two objects, A (hot) and B (cold), in thermal contact. Heat flows from A to B until $T_A = T_B$, reaching thermal equilibrium. No net heat flow occurs at equilibrium.

* **Challenge:** Consider three objects A, B, and C. If A and B are in thermal equilibrium, and B and C are in thermal equilibrium, what can you conclude about A and C? Explain how this relates to the function of a thermometer.

specific heat capacity: Definition goes here

Syllabus Ref: PH11-10 (ACSPH020)

Working Scientifically: Problem Solving

Bloom's Level: Apply

Literacy Skills: Define specific heat capacity, Interpret heat capacity tables.

Numeracy Skills: Calculate thermal energy and temperature change using Q=mcΔT, Analyse experimental data.

Simulation: See 'media/specific$_heat_calorimetry_simulation.mp4$'.

Related HSC Question: HSC2021Q15

Investigation: Determining Specific Heat Capacity Experimentally

Aim: To experimentally determine the specific heat capacity of a metal block (e.g., aluminium).

Apparatus: Metal block of known mass, immersion heater, power supply, voltmeter, ammeter, thermometer, stopwatch, insulation.

Method Outline:

1. Measure the mass (m) of the metal block.
2. Record the initial temperature ($T_{initial}$) of the block.
3. Insert the heater and thermometer into holes in the block. Ensure good thermal contact (a drop of oil can help). Insulate the block.
4. Connect the heater to the power supply via the ammeter (series) and voltmeter (parallel).
5. Start the stopwatch and switch on the power supply simultaneously. Record voltage (V) and current (I).
6. Record the temperature (T) at regular intervals (e.g., every minute) for a set time (e.g., 10 minutes).
7. Switch off the power supply. Record the maximum temperature reached (T_{final}).

Analysis:

- Calculate the electrical energy supplied: $E = V \times I \times t$, where t is the total time in seconds.
- Assuming all electrical energy is converted to thermal energy absorbed by the block ($Q \approx E$), calculate $\Delta T = T_{final} - T_{initial}$.
- Rearrange $Q = mc\Delta T$ to find c: $c = \frac{Q}{m\Delta T} \approx \frac{VIt}{m\Delta T}$.
- Compare the experimental value with the known value and discuss sources of error (e.g., heat loss to surroundings, thermometer calibration, energy absorbed by heater/insulation).

Safety Checklist: [ ] Ensure electrical connections are secure. [ ] Do not touch the heater when hot. [ ] Place apparatus away from edge of bench.

Working Scientifically Focus: Conducting Investigations (PH11/12-3), Processing Data (PH11/12-4), Problem Solving (PH11/12-6).

Mechanisms of Heat Transfer

Thermal energy transfer occurs through three primary mechanisms: conduction, convection, and radiation. Often, more than one mechanism is active simultaneously.

Conduction

Conduction is the transfer of thermal energy through direct contact and collisions between adjacent particles (atoms, molecules, electrons) without the bulk movement of the substance itself. It is the primary mechanism of heat transfer in solids.

- **Mechanism:** Vibrating particles collide with neighbours, transferring kinetic energy. In metals, free electrons also play a significant role, making metals good thermal conductors.
- **Examples:** A metal spoon heating up in hot soup, heat travelling along an iron bar held in a flame.
- **Factors:** Depends on the material (thermal conductivity), temperature difference, cross-sectional area, and length.

Convection

Convection is the transfer of thermal energy through the bulk movement of fluids (liquids or gases). It occurs due to changes in density caused by temperature differences.

- **Mechanism:** When a fluid is heated from below, it expands, becomes less dense, and rises. Cooler, denser fluid sinks to take its place, creating a **convection current**.
- **Examples:** Boiling water in a pot, sea breezes, atmospheric circulation, central heating systems.
- **Types:** Natural convection (driven by density differences) and forced convection (driven by external means like fans or pumps).

Radiation

Radiation is the transfer of thermal energy via electromagnetic waves (primarily infrared radiation). Unlike conduction and convection, radiation does not require a medium and can travel through a vacuum.

Math Link: Ensure you can rearrange Equation 1 to solve for m, c, or ΔT. Pay close attention to units. A temperature *change* (ΔT) is the same in Kelvin and Celsius, but the absolute temperatures are different.

Substance	c (J kg^{-1} K^{-1})
Water (liquid)	4186
Ice (0°C)	2090
Aluminium	900
Copper	385
Air (typical)	1005

Figure 3: Approximate specific heat capacities of common substances. Note water's high value.

* **Challenge:** How would you modify the specific heat capacity experiment to account for heat loss to the surroundings more accurately? Research techniques like the method of mixtures or continuous flow calorimetry.

Syllabus Ref: PH11-10 (ACSPH016)

Bloom's Level: Understand

Literacy Skills: Describe energy transfer mechanisms, Compare mechanisms.

Numeracy Skills: Interpret insulation performance graphs.

Diagram Resource: See 'media/heat$_transfer_mechanisms.png$'.

Related HSC Question: HSC2018Q9a

Conduction: Definition goes here

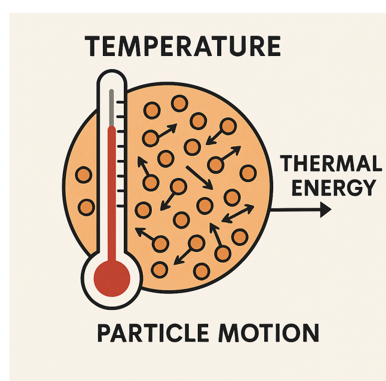

Figure 4: Conduction: Heat energy transferred through particle collisions along a solid rod.

Convection: Definition goes here

convection current: Definition goes here

- **Mechanism:** All objects above absolute zero emit thermal radiation. The rate of emission depends on temperature, surface area, and emissivity (a measure of how effectively a surface radiates). Hotter objects radiate more energy.
- **Examples:** Heat from the Sun reaching Earth, warmth felt near a campfire or radiator, thermal imaging cameras.
- **Surface Properties:** Dull, black surfaces are good absorbers and emitters of radiation, while shiny, light-coloured surfaces are poor absorbers/emitters but good reflectors.

Stop and Think

Explain how a thermos flask (vacuum flask) minimizes heat transfer by all three mechanisms (conduction, convection, radiation) to keep liquids hot or cold.

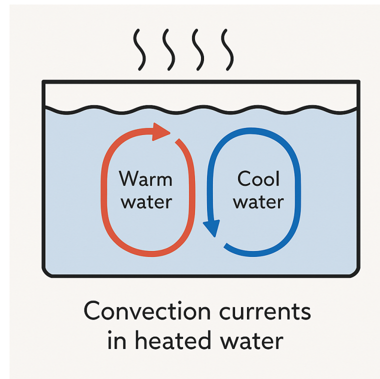

Figure 5: Convection currents in heated water. Warm, less dense water rises; cool, denser water sinks.
Radiation: Definition goes here

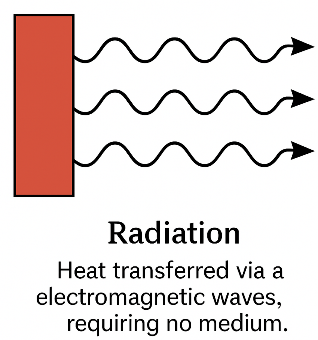

Figure 6: Radiation: Heat transferred via electromagnetic waves, requiring no medium.

* **Challenge:** Research the concept of thermal conductivity (for conduction), convective heat transfer coefficient (for convection), and emissivity (for radiation). How are these quantified and used in engineering applications like building insulation or heat exchanger design?

History: Early theories struggled to explain heat transfer through vacuum until James Clerk Maxwell's theory of electromagnetism (1860s) provided the basis for understanding thermal radiation.

Phase Changes and Latent Heat

When a substance absorbs or releases thermal energy, its temperature may change (as described by specific heat capacity), or it may undergo a **phase change** (e.g., melting, boiling, freezing, condensing) at a constant temperature. The energy involved in phase changes is called **latent heat**.

Key Concept: Latent Heat (L)

Latent heat (L) is the thermal energy absorbed or released per unit mass of a substance during a phase change at constant temperature and pressure.

- **Latent Heat of Fusion** (L_f): Energy required to change 1 kg of substance from solid to liquid (melting) or released when changing from liquid to solid (freezing).
- **Latent Heat of Vaporization** (L_v): Energy required to change 1 kg of substance from liquid to gas (boiling/evaporation) or released when changing from gas to liquid (condensation).

The thermal energy (Q) required for a mass (m) to undergo a phase change is given by:

$$Q = mL \tag{2}$$

The unit for latent heat is Joules per kilogram (J kg^{-1}).

During a phase change, the absorbed energy (latent heat) increases the potential energy of the particles (breaking intermolecular bonds) rather than their average kinetic energy (temperature). This is why the temperature remains constant during melting or boiling.

Example:

Calculate the total thermal energy required to convert 500 g of ice at 0°C to steam at 100°C. (Use $L_f(\text{water}) = 3.34 \times 10^5$ J kg^{-1}, $c(\text{water}) = 4186$ J kg^{-1} K^{-1}, $L_v(\text{water}) = 2.26 \times 10^6$ J kg^{-1})
Solution: This requires three steps: 1. Melting the ice at 0°C: $Q_1 = mL_f$ 2. Heating the water from 0°C to 100°C: $Q_2 = mc\Delta T$ 3. Boiling the water at 100°C: $Q_3 = mL_v$
Convert mass to kg: $m = 500\,\text{g} = 0.500\,\text{kg}$ Calculate ΔT for water heating: $\Delta T = 100C - 0C = 100$ K
1. $Q_1 = (0.500\,\text{kg}) \times (3.34 \times 10^5\,\text{J kg}^{-1}) = 1.67 \times 10^5$ J 2. $Q_2 = (0.500\,\text{kg}) \times (4186\,\text{J kg}^{-1}\,\text{K}^{-1}) \times (100\,\text{K}) = 2.093 \times 10^5$ J 3. $Q_3 = (0.500\,\text{kg}) \times (2.26 \times 10^6\,\text{J kg}^{-1}) = 1.13 \times 10^6$ J
Total energy: $Q_{total} = Q_1 + Q_2 + Q_3$ $Q_{total} = (1.67 + 2.093 + 11.3) \times 10^5$ J $Q_{total} = 15.063 \times 10^5$ J $\approx 1.51 \times 10^6$ J (or 1.51 MJ)
Therefore, approximately 1.51 MJ of energy is required.

Stop and Think

Why does steam at 100°C cause more severe burns than water at 100°C? Relate your answer to latent heat.

Chapter Summary Further Connections

This chapter explored fundamental thermodynamic concepts:

- **Temperature** relates to the average kinetic energy of particles.
- **Thermal Energy** is the total internal energy.
- **Thermal Equilibrium** is reached when there is no net heat flow (equal temperatures).
- **Specific Heat Capacity** ($Q = mc\Delta T$) quantifies energy needed for temperature change.
- **Heat Transfer Mechanisms** are conduction, convection, and radiation.
- **Latent Heat** ($Q = mL$) quantifies energy needed for phase changes at constant temperature.

phase change: Definition goes here
latent heat: Definition goes here

Syllabus Ref: PH11-10

Working Scientifically: Processing Data and Information
Bloom's Level: Analyse

Literacy Skills: Interpret phase change graphs.

Numeracy Skills: Calculate latent heat using Q=mL, Analyse heating/cooling curves rigorously.

Video Resource: See 'media/latent$_h$eat$_w$ater.mp4'.

Related HSC Question: HSC2019Q13b

Math Link: Be careful! Use $Q = mc\Delta T$ when temperature changes, and $Q = mL$ when phase changes occur at constant temperature. Problems often involve mul-
t

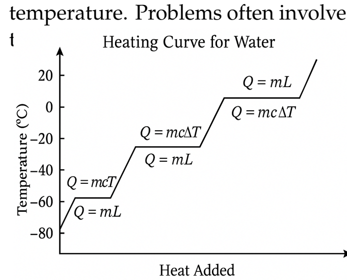

Figure 7: Heating curve for water. Sloped sections represent temperature increases (Q=mcΔT applies). Flat sections represent phase changes at constant temperature (Q=mL applies): melting at 0°C and boiling at 100°C.

These principles have broad applications, from understanding weather patterns and climate change (linking to Environmental Science and the cross-curriculum priority of Sustainability) to designing efficient engines and refrigeration systems. The energy changes involved in phase transitions and chemical reactions (studied in Chemistry) are also governed by thermodynamic principles. Developing solutions to global energy challenges relies heavily on applying and advancing our understanding of thermodynamics.

Practice Questions

Practice Questions - Basic

1. Define temperature in terms of particle motion.
2. State the formula for calculating thermal energy change related to specific heat capacity, defining each term.
3. List the three main mechanisms of heat transfer.
4. What is latent heat? Give one example of where it is relevant.
5. Calculate the energy required to heat 0.5 kg of aluminium from 20°C to 100°C. (Use $c_{Al} = 900$ J kg^{-1} K^{-1})

Practice Questions - Intermediate

1. Explain the difference between thermal energy and temperature using a macroscopic example (e.g., ocean vs boiling kettle).
2. Describe the process of reaching thermal equilibrium between a hot metal block and cool water in a calorimeter.
3. A 2.0 kW heater is used to heat 5.0 kg of water initially at 15°C for 3 minutes. Assuming no heat loss, calculate the final temperature of the water. (Use $c_{water} = 4186$ J kg^{-1} K^{-1})
4. Compare and contrast conduction and convection, giving examples where each is the dominant mode of heat transfer.
5. Calculate the energy released when 200 g of steam at 100°C condenses to water at 100°C. (Use $L_v(\text{water}) = 2.26 \times 10^6$ J kg^{-1})
6. Sketch a cooling curve (Temperature vs Time) for a substance that starts as a gas, cools, condenses to a liquid, cools further,

freezes to a solid, and finally cools as a solid. Label the sections corresponding to specific heat and latent heat.

Practice Questions - Advanced

1. A 100 g copper block at 90°C is placed into 300 g of water at 20°C in an insulated container. Calculate the final equilibrium temperature, assuming no heat loss to the container. (Use $c_{Cu} = 385$ J kg^{-1} K^{-1}, $c_{water} = 4186$ J kg^{-1} K^{-1}) *Hint: Heat lost by copper = Heat gained by water.*

2. Design an experiment to compare the effectiveness of different insulating materials (e.g., wool, foam, air gap) in reducing heat transfer by conduction and convection. Specify your independent, dependent, and controlled variables, and outline your method and data analysis approach. (Focus on experimental design and scientific process - PH11/12-3, PH11/12-6).

3. (PISA-style) A company is designing a new type of solar water heater for residential use. They are considering two designs: one using copper pipes painted black, and another using plastic pipes with a selective coating that absorbs sunlight well but emits little infrared radiation. Analyse the potential advantages and disadvantages of each design in terms of heat absorption (radiation), heat transfer to the water (conduction/convection), and heat loss to the environment (all three mechanisms). Justify which design might be more efficient overall, considering different climate conditions. (Focus on applying concepts to a real-world problem, evaluating designs - PH11-10, PH11/12-6, PH11/12-7).

4. Explain quantitatively why sweating is an effective cooling mechanism for the human body, even on a hot day when the surrounding air temperature might be higher than body temperature. Use the concept of latent heat of vaporization in your explanation.

5. How much energy is required to convert 1.0 kg of ice initially at -10°C completely into steam at 110°C? You will need specific heat capacities for ice and steam, in addition to water, plus both latent heats. (Requires finding additional data - PH11/12-4). (Example values: $c_{ice} \approx 2090$, $c_{steam} \approx 2010$ J kg^{-1} K^{-1}).