Module 3 · Lesson

# Thermodynamics

PH11-10

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## ORIENTATION

**Lesson goal:** distinguish temperature, heat, internal energy, specific heat, latent heat, and efficiency in practical thermal systems.

This lesson is language-sensitive. Students often write as if heat is stored in an object. In this course, heat is energy transferred because of a temperature difference.

## CORE CONTENT

Temperature is related to average particle kinetic energy. Heat is energy in transit due to temperature difference. Thermal energy calculations depend on whether the energy changes temperature or changes phase.

Key equations:

$$Q = mc\Delta T$$

$$Q = mL$$

$$\eta = \frac{E_{\text{useful}}}{E_{\text{input}}} \times 100$$

| QUANTITY | MEANING | UNIT |
| --- | --- | --- |
| $Q$ | energy transferred as heat | J |
| $m$ | mass | kg |
| $c$ | specific heat capacity | J kg^-1 K^-1 |
| $\Delta T$ | temperature change | K or deg C interval |

| QUANTITY | MEANING | UNIT |
| --- | --- | --- |
| $L$ | latent heat | J kg^-1 |
| $\eta$ | efficiency | % |

Use $Q = mc\Delta T$ when temperature changes. Use $Q = mL$ when phase changes at constant temperature.

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#### CONCEPT CHECK

1. Heat is best described as:

    - A. a substance stored in hot objects
    - B. energy transferred because of temperature difference
    - C. the same thing as temperature
    - D. always measured in degrees Celsius

    **Answer:** B.

2. During a phase change at constant temperature, the relevant equation is:

    - A. $Q = mc\Delta T$
    - B. $Q = mL$
    - C. $v = f\lambda$
    - D. $F = ma$

    **Answer:** B.

3. A material with larger specific heat capacity requires:

    - A. less energy for the same mass and temperature rise
    - B. more energy for the same mass and temperature rise
    - C. no energy to heat
    - D. only latent heat

    **Answer:** B.

4. Short response: explain why temperature can stay constant while energy is still being transferred into a substance.

## APPLIED PRACTICE

### Worked Example

Calculate the energy required to warm $0.75\ \mathrm{kg}$ of water from $18^\circ\mathrm{C}$ to $62^\circ\mathrm{C}$. Use $c = 4180\ \mathrm{J\ kg^{-1}K^{-1}}$.

1. Find temperature change:

$$\Delta T = 62 - 18 = 44\ \mathrm{K}$$

2. State the formula:

$$Q = mc\Delta T$$

3. Substitute:

$$Q = 0.75 \times 4180 \times 44$$

4. Calculate:

$$Q = 1.38 \times 10^5\ \mathrm{J}$$

**Final answer:** $1.38 \times 10^5\ \mathrm{J}$, or about $138\ \mathrm{kJ}$, assuming heat losses are negligible.

### Practice Problem

Calculate the energy required to heat $0.50\ \mathrm{kg}$ of aluminium by $35\ \mathrm{K}$ if $c = 900\ \mathrm{J\ kg^{-1}K^{-1}}$. Then state one experimental reason the measured energy input may be larger.

## DEEP PRACTICE AND WRITING

Prompt: analyse a calorimetry experiment where measured energy transfer is larger than the calculated energy gained by the water. Your answer must refer to system boundary, heat loss, and uncertainty.

Strong response pattern:

1. identify the ideal model,
2. state the calculated energy gain,
3. identify where additional energy may have gone,
4. judge how that affects reliability.

#### MAINTENANCE LOOP

Two-minute retrieval:

1. Choose between $Q = mc\Delta T$ and $Q = mL$.
2. State why the other equation is not appropriate.
3. Name one source of heat loss in a real experiment.

#### STUDENT WORKING