

Exercise walk-through

# 5.1

## Heating, phase change and thermistor calibration (125–128, CP12–13)

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Pearson Edexcel · International A-Level · Physics

## CP12–13: control what the equations assume

| Method                                | Measurement and control                                                                           |
|---------------------------------------|---------------------------------------------------------------------------------------------------|
| CP12: calibrate thermistor            | Stirred bath + reference thermometer; wait for equilibrium; fixed supply; repeat warming/cooling. |
| CP13: latent heat                     | Measure electrical power, time and mass change during steady phase change.                        |
| Correct approximately constant losses | $L = (P_2 - P_1)/(\dot{m}_2 - \dot{m}_1)$ at comparable phase-change temperature.                 |

### Use the evidence

The subtraction is justified by the constant-loss assumption, not by algebra alone.

## Nuclear equations conserve both rows

- 1 **Process** Beta-minus converts a neutron to a proton, electron and electron antineutrino.
- 2 **Example**  ${}^{14}_6\text{C} \rightarrow {}^{14}_7\text{N} + {}^0_{-1}\text{e} + {}^0_0\bar{\nu}_e$
- 3 **Check** Nucleon number:  $14 = 14 + 0 + 0$ . Charge number:  $6 = 7 - 1 + 0$ .
- 4 **Distinguish** Alpha lowers  $A$  by 4 and  $Z$  by 2; gamma changes neither. Energy and momentum still conserve.

## Check yourself

| Question                                                                       | Explanation                                                                                                                                     |
|--------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| Constant temperature but increasing internal energy?<br>Why remove background? | Molecular arrangements and potential energy can change during phase change.<br>It does not obey the test source's distance or time-decay model. |
| $a$ - $x$ gradient $-25 \text{ s}^{-2}$ ?                                      | $\omega = \sqrt{25 \text{ s}^{-2}} = 5.0 \text{ rad/s}$ . The negative sign indicates restoring acceleration.                                   |

## Exercise 2.1

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**2.1** A 0.25 kg aluminium block warms from 20 to 50 °C. Its specific heat capacity is  $900 \text{ J kg}^{-1} \text{ K}^{-1}$ . Calculate the energy increase. Explain why its temperature is not a measure of its total internal energy. [4]

Al

0.25 kg; 20 to 50 °C

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|    |
|----|
| Al |
|----|

0.25 kg; 20 to 50 °C

**2.1** The known mass and temperature rise require sensible heating.

$$\Delta E = mc\Delta\theta = (0.25 \text{ kg})(900 \text{ J kg}^{-1} \text{ K}^{-1})(50 - 20) \text{ K} = 6750 \text{ J}$$

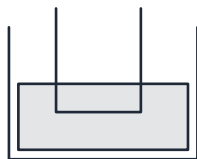
Energy. Temperature relates to average random kinetic energy; total internal energy also depends on amount and intermolecular potential energy/state.

## Exercise 2.2

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**2.2** A heater supplies 24 W for 300 s while ice melts at 0 °C. The mass melted is 0.020 kg. Calculate an uncorrected latent heat and explain how heat loss to surroundings affects it. [4]

24 W; 300 s



ice at 0 °C

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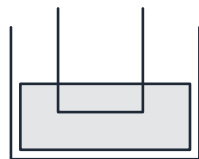
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24 W; 300 s



ice at 0 °C

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**2.2** At constant temperature, use phase-change energy.

$$L = \frac{Pt}{\Delta m} = \frac{(24 \text{ W})(300 \text{ s})}{0.020 \text{ kg}} = 3.6 \times 10^5 \text{ J kg}^{-1}$$

Value. If some heater energy escapes to surroundings, less causes melting; assigning all input to melting overestimates  $L$ . This assumes net loss, not extra melting caused by warm surroundings.

## Exercise 2.3

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**2.3** A 6.0 V supply feeds an upper 2.0 k $\Omega$  resistor and lower NTC thermistor. Thermistor resistance changes from 4.0 to 1.0 k $\Omega$  on warming. Find both output voltages across it and explain their trend. [4]

6.0 V

upper 2.0 k $\Omega$

lower NTC

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6.0 V

upper 2.0 kΩ

lower NTC

**2.3** Output is across the lower resistor, so use the divider relation.

$$V_{out,c} = V_s \frac{R_c}{R + R_c} = 6.0 \text{ V} \frac{4.0 \text{ k}\Omega}{(2.0 + 4.0) \text{ k}\Omega} = 4.0 \text{ V}$$

Cold value.

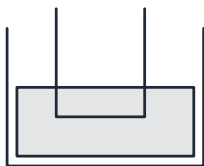
$$V_{out,w} = V_s \frac{R_w}{R + R_w} = 6.0 \text{ V} \frac{1.0 \text{ k}\Omega}{(2.0 + 1.0) \text{ k}\Omega} = 2.0 \text{ V}$$

Warm value. Warming reduces lower resistance and its share of supply voltage.

## Exercise 3.1

**3.1** An insulated flask contains 0.15 kg ice at 0 °C. A 200 W heater converts it to water at 20 °C in 400 s. Use  $L_f = 3.3 \times 10^5 \text{ J kg}^{-1}$  and  $c_w = 4200 \text{ J kg}^{-1} \text{ K}^{-1}$ . Calculate useful energy, efficiency and mean loss power. Explain the flat part of a temperature–time curve during melting. [7]

200 W; 400 s



0.15 kg ice

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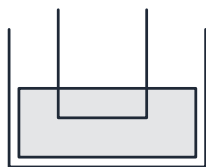
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200 W; 400 s



0.15 kg ice

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**3.1** Melting and warming the resulting water are separate stores.

$$E_u = mL_f + mc_w\Delta\theta$$

$$E_u = (0.15 \text{ kg})(3.3 \times 10^5 \text{ J kg}^{-1}) + (0.15 \text{ kg})(4200 \text{ J kg}^{-1} \text{ K}^{-1})(20 \text{ K}) = 62100 \text{ J}$$

## Full solution 3.1

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Useful energy.

$$E_{in} = Pt = (200 \text{ W})(400 \text{ s}) = 80000 \text{ J}$$

Input energy.

$$\eta = \frac{E_u}{E_{in}} = \frac{62100 \text{ J}}{80000 \text{ J}} = 0.776 = 77.6\%$$

Efficiency.

$$P_{loss} = \frac{E_{in} - E_u}{t} = \frac{(80000 - 62100) \text{ J}}{400 \text{ s}} = 44.8 \text{ W}$$

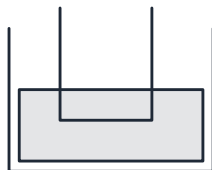
Loss power. Energy during melting changes molecular arrangement/potential energy, without raising average random kinetic energy/temperature during the ideal phase change.

## Exercise 3.2

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**3.2** In a steady boiling experiment, powers 40 and 60 W give mass-loss rates  $1.2 \times 10^{-5}$  and  $2.1 \times 10^{-5} \text{ kg s}^{-1}$ . Derive a heat-loss-corrected expression for latent heat, calculate it, and state the assumption enabling subtraction. [5]

40 W / 60 W



steady boiling

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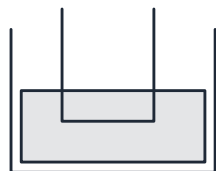
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40 W / 60 W



steady boiling

**3.2** At either steady power,  $P = L\dot{m} + P_{loss}$ . Subtract to eliminate the same loss power.

$$L = \frac{P_2 - P_1}{\dot{m}_2 - \dot{m}_1} = \frac{(60 - 40) \text{ W}}{(2.1 - 1.2) \times 10^{-5} \text{ kg s}^{-1}} = 2.22 \times 10^6 \text{ J kg}^{-1}$$

## Exercise 3.3

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**3.3** Design a calibration for the thermistor divider of 2.3 to switch a thermostat at  $45\text{ }^{\circ}\text{C}$ . Include an independent temperature measurement, equilibrium, controls, processing, one loading error and safety. Explain why two end-point readings alone may not be enough.[6]

thermistor

thermometer



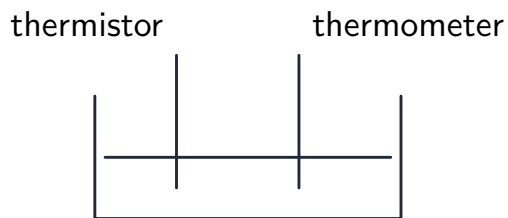
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**3.3** Place an independent thermometer beside the thermistor in a stirred water bath. Record multiple temperatures and outputs, waiting for equilibrium each time. Keep supply and fixed resistance unchanged. Plot a calibration and interpolate output at  $45\text{ }^{\circ}\text{C}$ ; the NTC relation may curve, so end points alone do not establish the switching voltage. Use a high-input-resistance voltmeter to avoid loading. Keep contacts dry/insulated and use low voltage with hot-water precautions.