Unit 9 · Heat and Temperature

ANSWER KEY · FOR TEACHERS

Full marks 33

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. thermal energy
2. heat
3. thermal equilibrium
4. zeroth law
5. thermometric property
6. calibration
7. absolute zero
8. kelvin

Each carries 0.5 mark. **K · 4**

2 Label the diagram

1. 0 °C
2. steam
3. capillary
4. bulb

Each carries 0.5 mark. **K · 2**

3 Multiple choice

i. **b.** joule **K · 1**

Heat is energy, so it is measured in joules (1 cal = 4.186 J). The kelvin is the unit of temperature.

ii. **c.** e.m.f. **K · 1**

Two junctions of different metals at different temperatures give an e.m.f. that depends on the temperature difference.

iii. **b.** 27 °C **A · 1**

$\theta = T - 273.15 = 26.85\ ^\circ\text{C} \approx 27\ ^\circ\text{C}$.

iv. **b.** impurities dissolved in the water raise its boiling point, but not the steam's temperature **U · 1**

Dissolved impurities raise the water's boiling point; the steam above it is at the true steam point for that pressure.

v. **c.** −273.15 °C **U · 1**

0 K = −273.15 °C (and −459.67 °F, on the Fahrenheit scale).

4 Short answers

a. **MARKING SCHEME** **U · 2**

- ✓ Heat is energy in transfer, measured in joules; temperature is the degree of hotness, measured in kelvin (or °C).
- ✓ Heat flows because of a temperature difference; temperature decides the direction of the flow (it measures the molecules' average kinetic energy).

b. **MARKING SCHEME** **U · 2**

- ✓ From the tea to the pool.
- ✓ Heat flows from higher to lower temperature, not from more thermal energy to less.

c. **MARKING SCHEME** **A · 3**

- ✓ $\theta = (R - R_0)/(R_{100} - R_0) \times 100$.
- ✓ The values put in.
- ✓ $\theta = 51.3\ ^\circ\text{C}$.

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5 Long answer

ANSWER U · 4

The bulb is put in pure melting ice; when the thread stops moving, its level is marked as the lower fixed point, 0 °C. Then the bulb is held in the steam just above pure water boiling at standard pressure (101.325 kPa); the level is marked as the upper fixed point, 100 °C. The stem between the marks is divided into 100 equal parts, each one degree.

The boiling point of water depends on pressure, so the steam point is defined at standard pressure. In Bhaktapur, about 1400 m up, water boils at only about 95 °C. A thermometer marked "100" there would be about 5 degrees out at that end, and every reading would be stretched (it would read too high).

MARKING SCHEME

- ✓ The lower fixed point marked in pure melting ice (0 °C).
- ✓ The upper fixed point in steam above pure boiling water (100 °C), and 100 equal parts between.
- ✓ The boiling point depends on pressure, so standard pressure is needed.
- ✓ In Bhaktapur water boils at about 95 °C, so the scale would be wrong (about 5 degrees at the top).

6 Numerical problems

a. **ANSWER** A · 4

i. $\frac{C}{5} = \frac{F - 32}{9}$: $C = 5 \times (98.6 - 32) \div 9 = \mathbf{37}\ ^\circ\mathbf{C}$.

ii. $T = 37 + 273.15 = \mathbf{310.15\ K}$ (about 310 K).

iii. A change: $\Delta K = \Delta C = (5/9)\ \Delta F = (5/9) \times 1.8 = \mathbf{1\ K}$.

MARKING SCHEME

- ✓ $C/5 = (F - 32)/9$.
- ✓ 37 °C.
- ✓ 310 K.
- ✓ A rise of 1 K ($\Delta K = 5/9\ \Delta F$).

b. **ANSWER** A · 4

i. $\frac{N - 20}{220 - 20} = \frac{C}{100}$, so $N = 20 + 2C = 20 + 100 = \mathbf{120}\ ^\circ\mathbf{N}$.

ii. $N = C$: $C = 20 + 2C$, so $C = \mathbf{-20}$: at −20 °C the N scale also reads −20 °N.

MARKING SCHEME

- ✓ $(N - 20)/200 = C/100$.
- ✓ N = 120 °N at 50 °C.
- ✓ Setting $N = C$ in $N = 20 + 2C$.
- ✓ −20 °C.

7 Think

ANSWER HA · 3

A thermometer reads its own temperature after it reaches thermal equilibrium with the body. To do so, heat flows between them. A drop has very little thermal energy compared with the thermometer's bulb, so the heat the bulb takes cools the drop a lot: they reach equilibrium at a temperature far below the drop's original one. A good thermometer must take very little heat from the body it measures.

MARKING SCHEME

- ✓ It reads the temperature at thermal equilibrium, after heat flows between them.
- ✓ The drop is tiny; the heat taken by the bulb lowers the drop's temperature a lot.
- ✓ So the reading is too low: the thermometer must be small compared with the body.

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8 Activity: Can your hands measure temperature?

(not marked)

WHAT STUDENTS SHOULD FIND

The left hand feels the lukewarm water as warm, the right hand as cool, though a thermometer gives one reading. The skin feels the flow of heat into or out of it, not the temperature: the cold hand gains heat, the warm hand loses it. That is why we need a thermometer, which reads the temperature at thermal equilibrium.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Which Feels Cooler?** (exhibit): The wood and the metal have long been in thermal equilibrium with the room, at one temperature, yet the metal feels colder to your hand.
- **Galileo Thermometer** (exhibit): A thermometer needs a property that changes steadily with temperature; this one uses the liquid's density: read the tag on the lowest bulb still floating.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	8	10	12	3	**33**