Unit 10 · Thermal Expansion

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 28

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

1 Spot the error

ANSWER U · 3

An area grows with the superficial expansivity, $\beta = 2\alpha$, not α: $A_2 = A_1(1 + 2\alpha\Delta\theta) = 2.0 \times (1 + 2 \times 2.3 \times 10^{-5} \times 50) =$ **2.0046 m²**. She found only half the increase.

MARKING SCHEME

- ✓ The mistake: α used for an area instead of $\beta = 2\alpha$.
- ✓ $A_2 = A_1(1 + \beta\Delta\theta)$ with $\beta = 2\alpha$.
- ✓ $A_2 = 2.0046\ m^2$.

2 Read the data

ANSWER A · 4

i. **Yes**: each 20 K rise adds 0.12 mm, so expansion ÷ rise is the same, 0.006 mm per K.

ii. $\alpha = \dfrac{S_2 - S_1}{l(\theta_2 - \theta_1)} = \dfrac{0.48 \times 10^{-3}}{0.500 \times 80} =$ **$1.2 \times 10^{-5}\ K^{-1}$**.

iii. **Iron.**

MARKING SCHEME

- ✓ Equal steps: 0.12 mm per 20 K, so proportional.
- ✓ $\alpha = \Delta l/(l\Delta\theta)$ with the values.
- ✓ $1.2 \times 10^{-5}\ K^{-1}$.
- ✓ Iron.

3 A rail with no gap

ANSWER A · 4

i. Stress $= Y\alpha\Delta\theta = 2.0 \times 10^{11} \times 1.1 \times 10^{-5} \times 30 =$ **$6.6 \times 10^7\ N/m^2$**. $F =$ stress $\times A = 6.6 \times 10^7 \times 60 \times 10^{-4} =$ **4.0×10^5 N** (about the weight of 40 tonnes).

ii. **No.** The strain it is prevented from having, $\Delta l/l = \alpha\Delta\theta$, doesn't depend on its length, so neither does the stress or the force.

MARKING SCHEME

- ✓ Stress $= Y\alpha\Delta\theta = 6.6 \times 10^7\ N/m^2$.
- ✓ $F = 4.0 \times 10^5$ N.
- ✓ No change with length.
- ✓ The strain $\alpha\Delta\theta$ is independent of length.

4 A clock in the Terai

ANSWER A · 3

Warmer, the pendulum is longer, so its period is longer: the clock **loses**. It loses $\frac{1}{2}\alpha\Delta\theta$ of its time: $\frac{1}{2} \times 1.9 \times 10^{-5} \times 15 \times 86\,400$ s = **12.3 s a day**.

MARKING SCHEME

- ✓ Longer pendulum, longer period: it loses.
- ✓ Fraction lost $\frac{1}{2}\alpha\Delta\theta$.
- ✓ About 12 s a day.

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5 Show that

ANSWER A · 3

The mass m stays the same while the volume grows: $V_2 = V_1(1 + \gamma\Delta\theta)$. So

$$\rho_2 = \frac{m}{V_2} = \frac{m}{V_1(1+\gamma\Delta\theta)} = \frac{\rho_1}{1+\gamma\Delta\theta}.$$

For small $\gamma\Delta\theta$, $\frac{1}{1+x} \approx 1 - x$, so $\rho_2 \approx \rho_1(1 - \gamma\Delta\theta)$.

The heated fluid is less dense than the cooler fluid around it, so it is pushed up (it floats in it).

MARKING SCHEME

- ✓ Mass constant, $V_2 = V_1(1 + \gamma\Delta\theta)$, so $\rho_2 = \rho_1/(1 + \gamma\Delta\theta)$.
- ✓ The approximation $1/(1 + x) \approx 1 - x$.
- ✓ Warm fluid is less dense, so it rises.

6 Predict, then explain

ANSWER U · 3

i. It bends with the **steel on the outside** of the curve (the brass on the inside), the opposite of when it is heated.

ii. Cooled, both metals shrink, but brass ($\alpha = 1.9 \times 10^{-5}\ K^{-1}$) shrinks more than steel ($1.1 \times 10^{-5}\ K^{-1}$). The shorter brass must be on the inside of the curve, the longer steel on the outside.

MARKING SCHEME

- ✓ Steel on the outside (brass inside).
- ✓ Brass contracts more than steel.
- ✓ The metal that ends up shorter is on the inside.

7 Correct the misconceptions

ANSWER U · 3

1. The atoms don't get bigger: they vibrate more strongly and so sit farther apart on average.
2. The hole gets **bigger**: every length on the plate, including the hole's diameter, grows as if the hole were filled with the same metal.
3. The level first falls a little, because the flask is heated and expands first; it rises once the liquid warms.

MARKING SCHEME

- ✓ Atoms vibrate more and sit farther apart; they don't grow.
- ✓ The hole gets bigger.
- ✓ The level first falls (the vessel expands first), then rises.

8 Think

ANSWER HA · 3

The steel rod's reading is **right**: the rod and the tape expand by the same fraction, so the rod still covers the same number of the tape's (stretched) marks as at 20 °C, its length at 20 °C.
The aluminium rod's reading is **more** than its length at 20 °C: aluminium expands by a larger fraction than the steel tape, so the hot rod covers more of the tape's marks. (It is still a little less than the rod's true hot length, since the tape's marks have spread apart too.)

MARKING SCHEME

- ✓ Same metal: both expand by the same fraction, so the reading is its length at 20 °C.
- ✓ The aluminium rod expands more than the tape's marks spread.
- ✓ Its reading is more than its length at 20 °C (less than its true hot length).

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9 Make your own

ANSWER HA · 2

The difference stays the same when both grow by the same amount: $l_s\alpha_s = l_b\alpha_b$, with $l_s - l_b = 10$ cm. So $l_s = 1.9\, l_b/1.1$, and $l_b(1.9/1.1 - 1) = 10$: l_b **= 13.75 cm,** l_s **= 23.75 cm**. Check: $23.75 \times 1.1 = 13.75 \times 1.9 = 26.1$ ($\times 10^{-5}$ cm per K): each grows equally.

MARKING SCHEME

- ✓ The condition $l_s\alpha$_s = $l_b\alpha$_b with $l_s - l_b = 10$ cm.
- ✓ 13.75 cm and 23.75 cm, checked.

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.

- **Galileo Thermometer** (exhibit): As the liquid warms it expands, so its density falls and the bulbs sink one by one: a liquid's expansion read as a temperature.
- **Lava Lamp — Convection in Motion** (exhibit): Heated at the bottom, the wax expands and its density falls below the liquid's, so it rises; cooled at the top, it contracts and sinks again.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	9	14	5	**28**

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