# Unit 17 · Magnetic Properties of Materials

**HARDER PRACTICE QUESTIONS · ANSWER KEY**

Full marks 31

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

Curie's law $\chi = C/T$ uses the **absolute** temperature, in kelvin. $T_1 = 310$ K and $T_2 = 410$ K, so $\chi_2 = 3.0 \times 10^{-4} \times \frac{310}{410} = \mathbf{2.3 \times 10^{-4}}$. In °C a temperature can be zero or negative, and $\chi = C/T$ would make no sense there.

**MARKING SCHEME**

- ✓ The error: the temperatures must be in kelvin.
- ✓ 310 K and 410 K.
- ✓ $\chi = 2.3 \times 10^{-4}$.

## 2 Read the data

**ANSWER** A · 4

(The readings are made up, in the way iron behaves.)

i. $\mu_r = B/\mu_0 H$: about **1990, 2390, 1990, 1290, 750**.

ii. It **rises, then falls**. At first the domain walls move easily and B rises fast; then the remaining domains turn; near saturation all point along the field and B hardly grows, so B/H falls.

iii. **No**: it depends on H (and on the iron's history), so a quoted $\mu r$ for iron is only a typical value.

**MARKING SCHEME**

- ✓ $\mu r = B/(\mu_0 H)$.
- ✓ The five values about 1990, 2390, 1990, 1290, 750.
- ✓ It rises then falls, as the domains grow, turn, and the iron saturates.
- ✓ Not fixed: it depends on H.

## 3 Predict, then explain

**MARKING SCHEME** U · 3

- ✓ The paramagnetic solution rises.
- ✓ Water falls slightly.
- ✓ Attracted into the stronger field (paramagnetic), pushed out of it (diamagnetic).

## 4 Show that

**MARKING SCHEME** A · 3

- ✓ $I = M/V$ with $M = m \times 2l$ and $V = A \times 2l$.
- ✓ $I = m/A$.
- ✓ Both in A/m.

## 5 Estimate it

**ANSWER** A · 3

Volume $= (5 \times 10^{-5})^3 = 1.25 \times 10^{-13}$ m$^3$; atoms $\approx 1.25 \times 10^{-13} \times 8.5 \times 10^{28} \approx \mathbf{10^{16}}$ (ten thousand trillion). Yes: within one domain all the atomic magnetic moments are lined up, so it is magnetized to saturation.

**MARKING SCHEME**

- ✓ Volume $1.25 \times 10^{-13}$ m$^3$.
- ✓ About $10^{16}$ atoms.
- ✓ All lined up in one domain (saturated).



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## 6 Which explanation fits?

**MARKING SCHEME** U · 2

- ✓ B, currents in the outer core.
- ✓ Above its Curie temperature iron can't stay a permanent magnet.

## 7 Correct the misconceptions

**ANSWER** U · 3

1. Copper is **diamagnetic**: every substance answers a field, and copper is weakly repelled.
2. An unmagnetized nail **has** domains, each magnetized to saturation, pointing different ways so they cancel.
3. Soft iron has a **low coercivity** and loses its magnetism easily; permanent magnets are made of steel, alnico or neodymium magnets (high coercivity).

**MARKING SCHEME**

- ✓ Copper is diamagnetic (weakly repelled).
- ✓ The nail has domains pointing different ways.
- ✓ Permanent magnets need high coercivity (steel, alnico), not soft iron.

## 8 Work backwards

**ANSWER** A · 3

Curie's law: $C = \chi T = 4.8 \times 10^{-4} \times 250 = 0.12$ K. Then $T = \dfrac{C}{\chi} = \dfrac{0.12}{3.0 \times 10^{-4}} = 400$ K = **127 °C**.

**MARKING SCHEME**

- ✓ $C = \chi T = 0.12$ K.
- ✓ $T = C/\chi = 400$ K.
- ✓ 127 °C.

## 9 Design it

**MARKING SCHEME** A · 3

- ✓ Transformer core X: small loop area, little loss.
- ✓ Permanent magnet Y: high coercivity.
- ✓ Crane X (low coercivity, so it lets go when switched off).

## 10 What if?

**ANSWER** HA · 2

The dip needle, horizontal at the equator, tips more and more until it is vertical ($\delta = 90°$) at the pole. The compass is turned by $B_H = B \cos \delta$, which shrinks to zero at the pole, so it turns more and more sluggishly and at the pole points nowhere in particular.

**MARKING SCHEME**

- ✓ The dip needle tips from horizontal to vertical.
- ✓ The compass weakens and points nowhere at the pole ($B_H = 0$).

## 11 Make your own

**ANSWER** HA · 2

For example: "In a magnetizing field of 1000 A/m, a material's intensity of magnetization is $4.99 \times 10^5$ A/m. Find its relative permeability." $\chi = I/H = 499$, $\mu r = 1 + \chi = 500$. Any problem whose numbers give $\mu r = 500$ is right.

**MARKING SCHEME**

- ✓ A sensible problem.
- ✓ Solved correctly to $\mu r = 500$.



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## 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.

- **Magnetic Lines of Force** (exhibit): The screws are ferromagnetic: near the magnet their domains line up with its field, so each becomes a magnet itself and is pulled strongly.
- **Earth's Magnetic Field** (exhibit): Find Nepal, where the declination is close to zero, then places where a compass points far east or west of true north.

| Marks by level | Knowledge | Understanding | Application | Higher ability | Total |
|---|---|---|---|---|---|
| **Marks** | 0 | 11 | 16 | 4 | **31** |



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