Unit 17 · Magnetic Properties of Materials

ANSWER KEY · FOR TEACHERS

Full marks 34

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

1 Key words

i. ✓ **True** K · 4

ii. ✗ **False**: It is the magnetic moment per unit volume, I = M/V.

iii. ✓ **True**

iv. ✗ **False**: Slightly more than 1; a diamagnetic substance's is slightly less than 1.

v. ✓ **True**

vi. ✗ **False**: It becomes paramagnetic.

vii. ✓ **True**

viii. ✗ **False**: It is 0° at the magnetic equator and 90° at the magnetic poles.

Each carries 0.5 mark.

2 Label the graph

1. retentivity Ob
2. coercivity Oc
3. saturation
4. H

K · 2

Each carries 0.5 mark.

3 Multiple choice

i. **b.** 1.0×10^{-4} A · 1

By Curie's law $\chi = C/T$, so χ falls in proportion as T rises: $1.5 \times 10^{-4} \times 300/450 = 1.0 \times 10^{-4}$.

ii. **b.** 43 μT A · 1

$B_H = B \cos \delta = 50 \times \cos 30^\circ = 43$ μT. (25 μT is the vertical component, B sin δ.)

iii. **c.** A/m K · 1

I = M/V, in (A m^2)/m^3 = A/m, the same unit as H.

iv. **c.** a high coercivity U · 1

A high coercivity means stray fields and knocks can't demagnetize it. A small loop and high permeability suit a transformer core instead.

v. **b.** domains pointing along the field grow at the expense of the others U · 1

In a weak field the domain walls move: domains along (or nearly along) the field grow. Only in a strong field do the remaining domains turn.

4 Short answers

a. MARKING SCHEME U · 2

✓ The magnet's field makes the nail a magnet (induced magnetism).

✓ Its nearer end is an opposite pole, and opposite poles attract.

b. MARKING SCHEME U · 2

✓ Bismuth across the field, because it is diamagnetic (weakly repelled).

✓ Aluminium along the field, because it is paramagnetic (weakly attracted).

c. MARKING SCHEME U · 2

✓ Ferromagnetism comes from domains of lined-up atomic magnets.

✓ Heat breaks down the lining up; above the Curie temperature the domains are gone (paramagnetic).

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5 Long answer

ANSWER U · 4

Permeability $\mu = B/H$, the magnetic induction produced per unit magnetizing field. Susceptibility $\chi = I/H$, the intensity of magnetization per unit magnetizing field (no unit).
With $I = \chi H$, $B = \mu_0(H + \chi H) = \mu_0 H(1 + \chi)$. Dividing by H, $\mu = \mu_0(1 + \chi)$, and dividing by μ_0, $\mu_r = 1 + \chi$.
A diamagnetic substance has χ small and negative, so its μr is slightly less than 1.

MARKING SCHEME

- ✓ $\mu = B/H$ and $\chi = I/H$ defined.
- ✓ $I = \chi H$ put into $B = \mu_0(H + I)$, giving $B = \mu_0 H(1 + \chi)$.
- ✓ $\mu = \mu_0(1 + \chi)$, so $\mu r = 1 + \chi$.
- ✓ Diamagnetic: χ negative, so μr slightly less than 1.

6 Numerical problems

a. **ANSWER** A · 4

i. $n = 240 \div 0.40 = 600$ turns/m; $H = nI = 600 \times 1.5 =$ **900 A/m**.
ii. $B = \mu_0\mu_r H = 4\pi \times 10^{-7} \times 800 \times 900 =$ **0.90 T**.
iii. $\chi = \mu r - 1 =$ **799**.
iv. $I = \chi H = 799 \times 900 =$ **7.2×10^5 A/m**.

MARKING SCHEME

- ✓ H = 900 A/m.
- ✓ B = 0.90 T.
- ✓ $\chi = 799$.
- ✓ $I = 7.2 \times 10^5$ A/m.

b. **ANSWER** A · 3

Energy per cycle $= 180 \times 1500 \times 10^{-6} = 0.27$ J; power $= 0.27 \times 50 =$ **13.5 W**.
In a day: $13.5 \times 86\,400 = 1.17 \times 10^6$ J = **0.32 kWh**.

MARKING SCHEME

- ✓ 0.27 J lost in each cycle.
- ✓ 13.5 W.
- ✓ 0.32 kWh in a day.

c. **ANSWER** A · 3

$B = \sqrt{B_H^2 + B_V^2} = \sqrt{30^2 + 40^2} =$ **50 μT**.
$\tan\delta = B_V/B_H = 40/30$, so $\delta =$ **53°**.

MARKING SCHEME

- ✓ $B = \sqrt{B_H^2 + B_V^2}$.
- ✓ B = 50 μT.
- ✓ $\delta = 53°$.

7 Think

ANSWER HA · 3

Below 20 °C gadolinium is ferromagnetic, so it is strongly attracted. In the sun it warms above 20 °C, its domains break up and it becomes only paramagnetic, so the attraction is too weak to lift it. Iron's Curie temperature is 770 °C, far above the warmth of a hand, so the nail stays ferromagnetic and is picked up as before.

MARKING SCHEME

- ✓ Below 20 °C ferromagnetic: strongly attracted.
- ✓ Above it paramagnetic: too weakly attracted to be lifted.
- ✓ Iron's Curie temperature (770 °C) is far higher, so a warm nail is still picked up.

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8 Activity: Make a magnet, then spoil it (Activity 17.2)

(not marked)

WHAT STUDENTS SHOULD FIND

Before stroking, no pins. After stroking, the needle picks up pins, and one end attracts the compass's north pole while the other repels it: it is a magnet, its domains lined up and staying so (steel has a large retentivity and coercivity). After the knocks it holds fewer pins: the jolts let some domain walls slip back, so it is partly demagnetized.

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	7	12	12	3	**34**

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