Unit 14 · Electricity and Magnetism

ANSWER KEY · FOR TEACHERS

Full marks 49

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. paramagnetic
2. domains
3. secondary
4. shunt
5. multiplier
6. semiconductor
7. doping
8. base

K · 4

Each carries 0.5 mark.

2 Label the diagram

1. scale
2. pointer
3. soft iron core
4. hairspring

K · 2

Each carries 0.5 mark.

3 True or false

i. ✗ **False**: Each cell gives about 2 V however big it is; its size decides how much charge it stores.

ii. ✓ **True**

iii. ✗ **False**: It must have a very high resistance, so that it takes almost no current.

iv. ✓ **True**

v. ✗ **False**: That is soft materials; hard materials keep it, and make permanent magnets.

vi. ✓ **True**

U · 3

Each carries 0.5 mark.

4 Multiple choice

i. **c.** loses its magnetism completely — K · 1

In a paramagnetic material, heat scatters the atomic magnets again as soon as the field is gone, so no magnetism is left.

ii. **c.** lead sulphate on both plates — U · 1

Discharging turns both the lead dioxide of the positive plate and the spongy lead of the negative plate into lead sulphate, $PbSO_4$.

iii. **c.** make the magnetic field strong and radial — U · 1

The soft-iron cylinder inside the coil concentrates the field in the narrow gaps and points it along the radius, so the turning effect is the same at every angle and the scale is even. The current goes in and out through the hairsprings.

iv. **c.** boron — K · 1

Boron has three outer electrons, one fewer than silicon, so each boron atom leaves a hole: a p-type semiconductor. Phosphorus and arsenic, with five, make n-type silicon; germanium is itself a semiconductor with four.

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v. **c.** a diode U · 1

A diode lets current through in one direction only, so it passes only the halves of an a.c. wave that drive it forward: rectification. A transformer changes the size of an a.c. voltage but leaves it a.c.

5 Very short answers

a. MARKING SCHEME K · 1

✓ Six.

b. MARKING SCHEME A · 1

✓ About 14 hours.

c. MARKING SCHEME K · 1

✓ About 0.7 V.

6 Short answers

a. MARKING SCHEME U · 2

✓ Ferromagnetic: the atomic magnets are already lined up in domains, and a field turns whole domains.

✓ Paramagnetic: heat keeps them random, and a field lines up only a tiny share of them.

b. MARKING SCHEME U · 2

✓ Near the end of charging, water in the acid is split into hydrogen and oxygen.

✓ Together they make an explosive mixture, which a flame or a spark can set off.

c. MARKING SCHEME U · 2

✓ An ammeter is in series; a large resistance would reduce the current it measures.

✓ A voltmeter is in parallel; a low resistance would take current from the part and change the voltage it measures.

d. MARKING SCHEME K · 2

✓ A primary cell can't be recharged; a secondary cell can be, many times.

✓ A primary cell's reaction is irreversible; a secondary cell's is reversed by charging (or any other correct difference).

e. MARKING SCHEME K · 2

✓ p-type: an element with three outer electrons is added; n-type: an element with five.

✓ In p-type the charges that move are mostly holes; in n-type, mostly free electrons.

7 Long answers

a. ANSWER U · 4

At the negative plate: $Pb + SO_4^{2-} \rightarrow PbSO_4 + 2e^-$.
At the positive plate: $PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4 + 2H_2O$.
Overall: $Pb + PbO_2 + 2H_2SO_4 \rightarrow 2PbSO_4 + 2H_2O$.
During charging, a current passed the other way reverses every reaction: $2PbSO_4 + 2H_2O \rightarrow Pb + PbO_2 + 2H_2SO_4$. Lead dioxide and lead are formed again on the plates, and the sulphuric acid becomes stronger again.

MARKING SCHEME

✓ Negative plate: $Pb + SO_4^{2-} \rightarrow PbSO_4 + 2e^-$.

✓ Positive plate: $PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4 + 2H_2O$.

✓ Charging: a current passed the other way reverses every reaction.

✓ Lead dioxide and lead form again on the plates, and the acid becomes stronger.

b. ANSWER

A transistor is a three-layer semiconductor device, npn or pnp, with three terminals: emitter, base and collector. A small current into the base controls a much larger current between the collector and the emitter, typically about 100 times bigger. As a switch: with no base current it is off; a small base current turns on a large collector current, as in an automatic night light, where an LDR sets the base voltage, or in a computer chip. As an amplifier: a small, changing base current (from a microphone, say) makes

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a large collector current that changes in the same way, a stronger copy of the signal that can drive a loudspeaker. U · 4

MARKING SCHEME

- ✓ Three layers (npn or pnp) and three terminals: emitter, base, collector.
- ✓ A small base current controls a much larger collector current, typically about 100 times bigger.
- ✓ Switch: no base current, off; a small base current turns on a large collector current.
- ✓ Amplifier: a small, changing base current makes a large collector current that changes in the same way.

8 Numerical problems

a. **ANSWER** A · 3

$$S = \frac{0.01 \times 50}{2 - 0.01} = \frac{0.5}{1.99} = 0.251\ \Omega$$

Whole ammeter: $\frac{GS}{G+S} = \frac{50 \times 0.251}{50.251} = 0.25\ \Omega$. (Also: at full scale, 0.5 V drives 2 A through it, and $0.5 \div 2 = 0.25\ \Omega$.)

A shunt of 0.251 Ω; the ammeter's resistance is 0.25 Ω.

MARKING SCHEME

- ✓ $S = \frac{0.01 \times 50}{2 - 0.01}$.
- ✓ S = 0.251 Ω.
- ✓ Whole ammeter: $\frac{GS}{G+S} = 0.25\ \Omega$.

b. **ANSWER** A · 3

At full scale the p.d. across the coil is $I_g G = 0.002 \times 40 = 0.08$ V. The same p.d. is across the shunt, so the shunt carries $\frac{0.08}{0.04} = 2$ A.

$$I = I_g + I_S = 0.002 + 2 = 2.002\ \text{A}$$

About 2 A.

MARKING SCHEME

- ✓ P.d. across the coil at full scale: $0.002 \times 40 = 0.08$ V.
- ✓ Shunt current: $0.08 \div 0.04 = 2$ A.
- ✓ Total 2.002 A, about 2 A.

c. **ANSWER** A · 3

i. Power: $4 \times 10 + 60 = 100$ W. Energy: 100 W × 3 h = **300 Wh**.

ii. Charge: $\frac{300\ \text{Wh}}{12\ \text{V}}$ = **25 Ah** (the current is $100 \div 12 \approx 8.3$ A for 3 hours).

iii. If only half may be used, the battery must hold twice that: **50 Ah** at least. (Shops would choose a larger one, since the inverter loses some energy and old batteries hold less.)

MARKING SCHEME

- ✓ Power 100 W, so energy 300 Wh.
- ✓ Charge: $300 \div 12 = 25$ Ah.
- ✓ Smallest capacity: $2 \times 25 = 50$ Ah.

d. **ANSWER** A · 2

The resistor must take the rest of the voltage: $5 - 2 = 3$ V, at 20 mA = 0.02 A.

$$R = \frac{3}{0.02} = 150\ \Omega$$

150 Ω in series. Without it, the LED would take far too much current and burn out.

MARKING SCHEME

- ✓ The resistor takes $5 - 2 = 3$ V at 0.02 A.
- ✓ $R = 3 \div 0.02 = 150\ \Omega$.

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9 Think

ANSWER HA · 3

The base voltage would now be the share of the 6 V across the fixed resistor, which is the lower part. In daylight the LDR's resistance is low (1 kΩ), so the base gets $6 \times 10/11 \approx 5.5$ V and the transistor is on; in the dark (100 kΩ) the base gets $6 \times 10/110 \approx 0.55$ V and it is off. **The lamp would come on in the light and go off in the dark**: a circuit that works as a light alarm, for example to warn when a fridge or a darkroom door is opened.

MARKING SCHEME

- ✓ The base now gets the share of the 6 V across the fixed resistor.
- ✓ Daylight: about 5.5 V, so on. Dark: about 0.55 V, so off.
- ✓ The lamp comes on in the light and goes off in the dark.

10 Activity: Find the resistance of a resistor

(not marked)

WHAT STUDENTS SHOULD FIND

The ratio V ÷ I comes out about the same each time for a resistor: that is its resistance, by Ohm's law (for 10 Ω, about 1.4 V and 0.14 A with one cell). For a torch bulb, the ratio grows as more cells are added, because the filament gets hotter and a hot metal has a higher resistance.

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- **Magnetic Lines of Force** (exhibit): The screws are made of a ferromagnetic material: near the magnet their domains line up, so each screw becomes a magnet itself and is pulled strongly.
- **Solar House Model** (exhibit): The solar panels charge the battery by day, and it gives the energy back when sunlight is weak: a rechargeable battery, a secondary cell.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	14	20	12	3	**49**

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