12.3 Magnetic Fields of Current-Carrying Wires and the Biot-Savart Law

Name: _____ Class: _____ Date: _____ **Total: 9 marks**

KEY WORDS biot-savart law 毕奥 • magnetic field 磁场

Objective

Build the skills to answer exam questions on **magnetic fields of current-carrying wires and the Biot-Savart law**.

You must be able to:

- state the **Biot-Savart law** 毕奥-萨伐尔定律, $d\vec{B} = \dfrac{\mu_0}{4\pi}\dfrac{I\,d\vec{l}\times\hat{r}}{r^2}$
- calculate the field of a **long straight wire**, $B = \dfrac{\mu_0 I}{2\pi r}$
- find the field at the **centre of a circular loop**, $B = \dfrac{\mu_0 I}{2R}$
- use the **right-hand rule** for field direction

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ The Biot-Savart law

$d\vec{B} = \dfrac{\mu_0}{4\pi}\dfrac{I\,d\vec{l}\times\hat{r}}{r^2}$ gives the field of a small current element; integrate over the wire for the total field ($\mu_0 = 4\pi \times 10^{-7}$).

■ Standard results

- Long straight wire: $B = \dfrac{\mu_0 I}{2\pi r}$.
- Centre of a circular loop of radius R: $B = \dfrac{\mu_0 I}{2R}$.

■ Direction

Curl the right hand around the wire with the thumb along the current; the fingers give the field direction.

2 Practice

2.1 Find the field 0.050 m from a long wire carrying 8.0 A ($\mu_0 = 4\pi \times 10^{-7}$). [2]

2.2 State the rule used to find the direction of the field around a straight wire. [1]

2.3 Write the field at the centre of a circular loop of radius R carrying current I. [1]

3 Exam-style questions

3.1 The magnetic field of a long straight wire is [1]

- **A** $\dfrac{\mu_0 I}{2\pi r}$
- **B** $\dfrac{\mu_0 I}{2R}$
- **C** $\mu_0 n I$
- **D** BIL

3.2 The Biot-Savart law gives the field of a [1]

- **A** current element
- **B** point charge
- **C** capacitor
- **D** resistor

3.3 A circular loop of radius 0.10 m carries 5.0 A ($\mu_0 = 4\pi \times 10^{-7}$).

(a) Find the magnetic field at its centre. [2]

(b) State how the field changes if the current is doubled. [1]

Solutions

2.1 $B = \dfrac{\mu_0 I}{2\pi r} = \dfrac{(4\pi \times 10^{-7})(8.0)}{2\pi(0.050)} = 3.2 \times 10^{-5}$ T.

2.2 the right-hand rule (grip rule).

2.3 $B = \dfrac{\mu_0 I}{2R}$.

3.1 **A**.

3.2 **A**.

3.3 (a) $B = \dfrac{\mu_0 I}{2R} = \dfrac{(4\pi \times 10^{-7})(5.0)}{2(0.10)} = 3.1 \times 10^{-5}$ T. (b) it doubles ($B \propto I$).