

# Biot-Savart, ampère and magnetic sources

AP Physics C (Mechanics and E&M, calculus-based) · Test answers (mark scheme)

Award marks as shown. Accept answers within rounding and carry a correct method through from an earlier slip. Remove a mark once for a missing unit, and award a mark for each correct justification.

**Level:** AP Physics C (Mechanics and E&M, calculus-based) · **Curriculum:** AP PC:E&M Unit 12

## Question 1 Ampère's law (2 marks)

The line integral of  $B$  around a closed loop equals  $\mu_0$  times the net current through the loop,  $\oint B \cdot dl = \mu_0 I_{\text{enc}}$ . It is useful when the symmetry of the current lets  $B$  be constant and tangent (or perpendicular) on the chosen loop.

*Marking: 1 mark for the law; 1 mark for the symmetry condition.*

## Question 2 Long wire (2 marks)

$$B = \mu_0 I / (2\pi d) = (2 \times 10^{-7})(6.0) / 0.040 = \mathbf{3.0 \times 10^{-5} \text{ T}}.$$

*Marking: 1 mark for the formula; 1 mark for the answer with unit.*

## Question 3 Coil (3 marks)

Centre:  $B = \mu_0 NI / (2R) = (4\pi \times 10^{-7})(100) / (0.20) = \mathbf{6.3 \times 10^{-4} \text{ T}}$ . Axis:  $B = \mu_0 NI R^2 / [2(x^2 + R^2)^{3/2}] = 6.28 \times 10^{-4} \times (1/2)^{3/2} = \mathbf{2.2 \times 10^{-4} \text{ T}}$ .

*Marking: 1 mark for the centre formula; 1 mark for the centre value; 1 mark for the axis value.*

## Question 4 Solenoid (3 marks)

$n = 1500 / 0.50 = 3000 \text{ m}^{-1}$ .  $B = \mu_0 nI = (4\pi \times 10^{-7})(3000)(3.0) = \mathbf{1.1 \times 10^{-2} \text{ T}}$ . Outside,  $B$  is **approximately zero**.

*Marking: 1 mark for  $n$ ; 1 mark for  $B$ ; 1 mark for the outside field.*

## Question 5 Inside a thick wire (3 marks)

Inside:  $B = \mu_0 I r / (2\pi R^2) = (2 \times 10^{-7})(6.0)(0.50 \times 10^{-3}) / (1.5 \times 10^{-3})^2 = \mathbf{2.7 \times 10^{-4} \text{ T}}$ . Outside:  $B = \mu_0 I / (2\pi r) = (2 \times 10^{-7})(6.0) / (3.0 \times 10^{-3}) = \mathbf{4.0 \times 10^{-4} \text{ T}}$ .

*Marking: 1 mark for the enclosed-current idea; 1 mark for each value.*

**Question 6 Parallel wires** (3 marks)

$F/L = \mu_0 I_1 I_2 / (2\pi d) = (2 \times 10^{-7})(12)(12)/0.050 = \mathbf{5.8 \times 10^{-4} \text{ N/m}}$ . The currents are in the same direction, so the force is **attractive**.

*Marking: 1 mark for the formula; 1 mark for the value; 1 mark for attractive.*

**Question 7 Zero field on the line** (2 marks)

The law has  $d\mathbf{B} \propto d\mathbf{l} \times \hat{\mathbf{r}}$ . On the line of the wire,  $d\mathbf{l}$  is parallel to  $\hat{\mathbf{r}}$ , so the cross product is zero for every element, and the total field is zero.

*Marking: 1 mark for the cross product; 1 mark for the parallel vectors.*

**Question 8 Toroid** (2 marks)

$B = \mu_0 NI / (2\pi r) = (2 \times 10^{-7})(250)(0.80)/0.050 = \mathbf{8.0 \times 10^{-4} \text{ T}}$ .

*Marking: 1 mark for the formula; 1 mark for the answer.*