InkPhysics

ANSWER BOOK

Force on a moving charge

Magnetic fields · Year 13

AQA 3.7.5.2 · CIE 20.3.1, 20.3.2, 20.3.3, 20.3.4, 20.3.5, 20.3.6 · OCR A 6.3.2(a), 6.3.2(b), 6.3.2(c)

19 questions · 52 marks

NAVY EDITION

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SECTION A · Warm-up

A1 $F = BQv$, where Q is the charge and v its speed (1); valid when the velocity is perpendicular to the field (1). [2]

A2 $F = BQv = 0.40 \times 1.6 \times 10^{-19} \times 2.0 \times 10^{6}$ (1)
$F = 1.28 \times 10^{-13}$ N (1) [2]

A3 The magnetic force is always perpendicular to the velocity, so it changes the direction of motion but not the speed (1); a force of constant magnitude always at right angles to the velocity acts as a centripetal force, producing circular motion (1). [2]

A4 The particle is stationary, since $F = BQv$ is zero when $v = 0$ (1); the particle moves parallel (or antiparallel) to the field, so it has no component of velocity at right angles to the field (1). [2]

A5 The electron is negative, so the conventional current is due south, opposite to its velocity (1); Fleming's left hand rule (field down, current south) gives a force that is horizontal, due east (1). [2]

A6 $F = BQv$, so the force doubles (1); $r = mv/BQ$, so the radius also doubles (1). [2]

SECTION B · Standard

B1 $BQv = mv^2/r$, so $r = mv/BQ$ (1) [3]
$r = (9.11 \times 10^{-31} \times 3.0 \times 10^{6})/(0.50 \times 1.60 \times 10^{-19})$ (1)
$r = 3.42 \times 10^{-5}$ m (1)

B2 $F = BQv = 0.80 \times 1.60 \times 10^{-19} \times 5.0 \times 10^{5}$ (1) [2]
$F = 6.40 \times 10^{-14}$ N (1)

B3 $r = mv/BQ = (1.67 \times 10^{-27} \times 5.0 \times 10^{5})/(0.80 \times 1.60 \times 10^{-19})$ (1) [2]
$r = 6.52 \times 10^{-3}$ m (1)

B4 The force is always perpendicular to the velocity (direction of motion) (1); work done requires a component of force along the displacement, and here there is none (1); so the speed and kinetic energy of the particle remain constant (1). [3]

B5 $r = mv/BQ$ (1) [3]
$= (6.64 \times 10^{-27} \times 1.5 \times 10^{7})/(0.25 \times 3.2 \times 10^{-19})$ (1)
$r = 1.25$ m (1)

B6 The electric force EQ balances the magnetic force BQv (1) [3]
$v = E/B = (4.5 \times 10^4)/0.30$ (1)
$v = 1.5 \times 10^5$ m s^{-1} (1)

B7 $BQv = mv^2/r$ gives momentum $p = mv = BQr = 1.2 \times 1.60 \times 10^{-19} \times 0.045$ (1) [2]
$p = 8.64 \times 10^{-21}$ kg m s^{-1} (1)

SECTION C · Stretch

C1 $E_k = eV = 8.00 \times 10^{-17}$ J (1) [4]
$v = \sqrt{(2E_k/m)} = 1.33 \times 10^7$ m s^{-1} (1)
$r = mv/BQ$ (1)
$r = 2.52 \times 10^{-4}$ m (1)

C2 $v = 2\pi r/T$ with $r = mv/BQ$ gives $T = 2\pi m/BQ$, independent of speed while m may be taken as constant, that is at non-relativistic speeds (1) [4]
$T = (2\pi \times 9.11 \times 10^{-31})/(0.50 \times 1.60 \times 10^{-19})$ (1)
$T = 7.15 \times 10^{-11}$ s (1)
$f = 1/T = 1.40 \times 10^{10}$ Hz (1)

C3 A uniform magnetic field, perpendicular to the plane of motion, bends the particles into semicircular paths inside two hollow dees (1). An alternating pd across the gap accelerates the particles each time they cross between the dees (1). As the speed increases the radius increases, so the particles spiral outwards until they exit at high energy (1). [3]

C4 $r = mv/BQ$ rearranged: $m = BQr/v$ (1) [4]
$m = (0.85 \times 1.60 \times 10^{-19} \times 0.024)/(3.0 \times 10^6)$ (1)
$m = 1.09 \times 10^{-27}$ kg (1)
This is only about two thirds of the proton mass of 1.67×10^{-27} kg, so the particle is not a proton (1)

C5 $r = mv/BQ$ rearranged: $v = BQr/m = (1.5 \times 1.60 \times 10^{-19} \times 0.60)/(1.67 \times 10^{-27})$ (1) [4]
$v = 8.62 \times 10^7$ m s^{-1} (1)
$E_k = ½mv^2$ (1)
$E_k = 6.21 \times 10^{-12}$ J (1)

C6 The charge carriers drifting through the slice move through the field, so each feels a magnetic force BQv that pushes it towards one face (1). Charge builds up on that face until the electric force it produces balances the magnetic force, leaving a steady pd, the Hall voltage, across the faces (1). The Hall voltage is proportional to B, so a calibrated probe reads the flux density directly (1). [3]