B13 · Extra practice, worked solutions

Electric and magnetic fields together | Diploma-style set of 8

Easy · B13-X01. An electron is in a uniform electric field of 800 N/C. Use e = 1.60 × 10^{-19} C. Find the size of the electric force on it, in newtons.

1. Givens: E = 800 N/C; q = 1.60 × 10^{-19} C. Question: F.

2. F = qE.

3. F = (1.60 × 10^{-19})(800) = 1.28 × 10^{-16} N.

4. Answer: 1.28 × 10^{-16} N

Easy · B13-X02. A velocity selector has an electric field of 2400 N/C and a magnetic field of 4.00 × 10^{-3} T at right angles. Find the speed of the particles that go straight through, in m/s.

1. Givens: E = 2400 N/C; B = 4.00 × 10^{-3} T. Question: v.

2. Going straight means the forces balance: qE = qvB, so v = E ÷ B.

3. v = 2400 ÷ (4.00 × 10^{-3}) = 6.00 × 10^{5} m/s.

4. Answer: 6.00 × 10^{5} m/s

Easy · B13-X03. Which particles go straight through a velocity selector set to E and B?

A. Only particles with the same mass as a proton
B. Only positive particles
C. Only particles with a charge of 1.60 × 10^{-19} C
D. Those with speed v = E/B, whatever their mass or charge

1. Givens: a velocity selector with fields E and B. Question: which particles go straight.

2. The charge q cancels from qE = qvB, and the mass never appears.

3. So any particle with v = E/B goes straight through.

4. Answer: D. Those with speed v = E/B, whatever their mass or charge

Medium · B13-X04. A proton enters a region with an electric field of 900 N/C and a magnetic field of 1.00×10^{-3} T. It moves at 3.00×10^{5} m/s at right angles to the magnetic field. The two forces act in opposite directions. Use $e = 1.60 \times 10^{-19}$ C. Find the size of the net force on it, in newtons.

1. Givens: E = 900 N/C; B = 1.00×10^{-3} T; v = 3.00×10^{5} m/s; q = 1.60×10^{-19} C; forces opposite. Question: Fnet.

2. Electric force: qE = $(1.60 \times 10^{-19})(900) = 1.44 \times 10^{-16}$ N.

3. Magnetic force: qvB = $(1.60 \times 10^{-19})(3.00 \times 10^{5})(1.00 \times 10^{-3}) = 4.80 \times 10^{-17}$ N.

4. Opposite directions, so subtract: Fnet = $1.44 \times 10^{-16} - 4.80 \times 10^{-17} = 9.60 \times 10^{-17}$ N.

5. Answer: 9.60×10^{-17} N

Medium · B13-X05. A velocity selector is set to pass speed v. A particle enters faster than v. Which force is larger, and what happens?

A. The electric force is larger, so the particle bends toward the side that the magnetic force pushes.

B. The magnetic force is larger, so the particle bends toward the side that the magnetic force pushes.

C. The two forces stay equal, so it goes straight.

D. The magnetic force is zero, so it follows the electric force.

1. Givens: the particle speed is greater than E/B. Question: which force is larger and what happens.

2. The electric force qE does not depend on speed. The magnetic force qvB grows with speed, so it is now the larger one.

3. The net force is toward the direction of the magnetic force, so the path bends that way.

4. Answer: B. The magnetic force is larger, so the particle bends toward the side that the magnetic force pushes.

Medium · B13-X06. The plates of a velocity selector are 0.0200 m apart with 500 V across them. The magnetic field is 0.0500 T. Find the speed of the particles that go straight, in m/s.

1. Givens: ΔV = 500 V; Δd = 0.0200 m; B = 0.0500 T. Question: v.

2. Field between plates: E = ΔV/Δd = 500 ÷ 0.0200 = 2.50×10^{4} V/m.

3. Straight through: v = E ÷ B = $2.50 \times 10^{4} \div 0.0500 = 5.00 \times 10^{5}$ m/s.

4. Answer: 5.00×10^{5} m/s

Challenging · B13-X07. An electron starts from rest and is accelerated through 400 V, then enters a velocity selector with a magnetic field of 2.00×10^{-3} T. Use $e = 1.60 \times 10^{-19}$ C and $m_e = 9.11 \times 10^{-31}$ kg. Find the electric field that lets it go straight through, in N/C.

1. Givens: starts from rest; $\Delta V = 400$ V; $B = 2.00 \times 10^{-3}$ T; $q = 1.60 \times 10^{-19}$ C; $m = 9.11 \times 10^{-31}$ kg. Question: E.

2. Speed from energy: $v = \sqrt{(2q\Delta V \div m)} = \sqrt{(2 \times (1.60 \times 10^{-19})(400) \div (9.11 \times 10^{-31}))} = 1.185 \times 10^{7}$ m/s (shown to 4 digits; keep the full value on your calculator).

3. Straight through: $E = vB = (1.185 \times 10^{7})(2.00 \times 10^{-3}) = 2.37 \times 10^{4}$ N/C.

4. Answer: 2.37×10^{4} N/C

Challenging · B13-X08. A velocity selector passes a proton of speed v. Explain why an electron of the same speed v also goes straight through, even though the forces on it point the other way.

1. Givens: a selector set so that a proton at speed v goes straight. Question: why an electron at the same speed also goes straight.

2. For the electron, both the electric force qE and the magnetic force qvB reverse, because the charge is negative.

3. They are still equal in size and now still opposite in direction, so the net force is still zero. The charge cancels in $qE = qvB$, so only the speed matters: $v = E/B$.