D.3 Motion in electromagnetic fields

Practice Worksheet — name: ________________________ date: _____________

FORMULAS FOR THIS TOPIC

FORCE ON A MOVING CHARGE $F = qvB\sin\theta$ FORCE ON A CONDUCTOR $F = BIL\sin\theta$

RADIUS IN A MAGNETIC FIELD $r = \frac{mv}{qB}$ PARALLEL WIRES (PER LENGTH) $\frac{F}{L} = \mu_0\frac{I_1 I_2}{2\pi r}$ VELOCITY SELECTOR $v = \frac{E}{B}$

SECTION A — MULTIPLE CHOICE

A1. A magnetic force never changes the kinetic energy of a charged particle because:

- (A) The force is too small
- (B) The force is always perpendicular to the velocity, so it does no work
- (C) Magnetic fields do not exert forces on charges
- (D) Kinetic energy is conserved in all fields

A2. An electron and a proton enter the same magnetic field with the same velocity. Compared with the proton, the electron's circular path has:

- (A) A much smaller radius, curving the opposite way
- (B) A much larger radius, curving the opposite way
- (C) The same radius, curving the same way
- (D) A much smaller radius, curving the same way

A3. Two long parallel wires carry currents in the same direction. They:

- (A) Repel each other
- (B) Attract each other
- (C) Exert no force on each other
- (D) Rotate to become perpendicular

SECTION B — SHORT ANSWER

B1. An electron ($m = 9.11 \times 10^{-31}$ kg) moving at 2.0×10^{7} m s^{-1} enters a 0.50 mT field perpendicularly. Calculate the radius of its path. [3 marks]

B2. In a velocity selector, an electric field of 3.0×10^4 V m^{-1} is crossed with a magnetic field of 0.060 T. Determine the speed of ions that pass undeflected, and state what happens to faster ions. [3 marks]

B3. A horizontal wire of length 0.30 m carrying 4.0 A lies perpendicular to a horizontal 0.25 T field. Calculate the force on the wire, and state the condition for the wire to "float". [3 marks]

ANSWER KEY

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Section A

A1: The force is always perpendicular to the velocity, so it does no work — $W = Fs\cos\theta$ with $\theta = 90^\circ$ gives zero at every instant: the force steers without speeding or slowing. Electric fields, by contrast, do work and change kinetic energy.

A2: A much smaller radius, curving the opposite way — $r = mv/qB$: same speed and charge magnitude, but the electron's mass is ~1836 times smaller, so its radius shrinks by the same factor. Opposite charge sign reverses the force direction, hence the opposite sense of rotation.

A3: Attract each other — Each wire sits in the magnetic field of the other; applying $F = BIL$ with the field directions shows attraction for parallel currents and repulsion for antiparallel. This force defined the ampere.

Section B

B1: $r = \frac{mv}{qB} = \frac{(9.11\times10^{-31})(2.0\times10^{7})}{(1.6\times10^{-19})(5.0\times10^{-4})} \approx 0.23\text{ m}$. Weak fields and fast electrons give conveniently laboratory-sized circles.

B2: Undeflected means $qE = qvB$, so $v = E/B = 3.0\times10^{4}/0.060 = 5.0\times10^{5}\text{ m s}^{-1}$. Faster ions experience a magnetic force (qvB) exceeding the electric force and deflect towards the magnetic-force side.

B3: $F = BIL = 0.25\times4.0\times0.30 = 0.30\text{ N}$. It floats if this force is directed vertically upward (right-hand/motor rule) and equals the weight: $BIL = mg$, i.e. the wire's mass must be $0.30/9.81 \approx 31\text{ g}$.