

$$\textcircled{1} \quad (a) \quad \omega = \frac{QB}{m} > \frac{v}{r} \Rightarrow v = \frac{QB r}{m} = \frac{2(1.6 \times 10^{-19} \text{ C})(1.2 \text{ T})(0.045 \text{ m})}{(4.00 \text{ u})(1.66 \times 10^{-27} \text{ kg/u})}$$

$$= 2.6 \times 10^6 \text{ m/s}$$

$$(b) \quad T = \frac{2\pi r}{v} = \frac{2\pi(0.045 \text{ m})}{2.6 \times 10^6 \text{ m/s}} = 1.09 \times 10^{-7} \text{ s}$$

$$(c) \quad K = \frac{1}{2} m v^2 = \frac{1}{2} (4.00 \text{ u})(1.66 \times 10^{-27} \frac{\text{kg}}{\text{u}}) (2.6 \times 10^6 \frac{\text{m}}{\text{s}})^2$$

$$= 2.24 \times 10^{-14} \text{ J} \times \frac{1}{1.6 \times 10^{-19} \text{ J/eV}} = 1.40 \times 10^5 \text{ eV}$$

$$(d) \quad \Delta U + \Delta K = 0 \Rightarrow \Delta U = -\Delta K = q \Delta V$$

$$\Delta V = \frac{\Delta U}{q} = -\frac{\Delta K}{q} = -\frac{1.4 \times 10^5 \text{ eV}}{2e} = \underline{\underline{-7.0 \times 10^4 \text{ V}}}$$

$$\textcircled{2} \quad \vec{\tau} = \vec{\mu} \times \vec{B}$$

$$|\vec{\mu}| = NIA \quad \text{in } +z \text{ direction}$$

$$|\vec{\tau}| = |\vec{\mu}| |\vec{B}| \sin(90^\circ + 30^\circ)$$

$$= NIA B \sin 120^\circ$$

$$= (20)(0.10 \text{ A})(0.10 \text{ m} \times 0.05 \text{ m})(0.5 \text{ T}) \sin 120^\circ$$

$$= 4.33 \times 10^{-3} \text{ N}\cdot\text{m}$$

Torque is in $-y$ direction by RHR.

③

Form the wire into N circular loops.

The circumference of each loop is L/N

The radius of each loop is $(L/N)/2\pi$

The area of each loop is $\pi r^2 = \pi (L/2\pi N)^2 = L^2/4\pi N^2$

The torque is $\vec{\mu} \times \vec{B}$ maximum is μB

$$\mu = NIA = NI \left(\frac{L^2}{4\pi N^2} \right) = \frac{L^2 I}{4\pi N}$$

maximum μ (giving maximum torque) occurs for $N=1$

$$\text{torque is } \frac{L^2 I B}{4\pi}$$

④

(a) $\text{emf} = vBL = (5.0 \text{ m/s})(1.2 \text{ T})(0.1 \text{ m}) = 0.60 \text{ V}$

(b) $I = \text{emf}/R = 0.60 \text{ V}/0.40 \Omega = 1.5 \text{ A}$

+ charges move to the top of the rod, so I is clockwise

(c) $\Delta E = P \Delta t = I^2 R \Delta t = (1.5 \text{ A})^2 (0.40 \Omega) (1 \text{ s}) = 0.90 \text{ J}$

(d) When a current I is flowing in the rod, there is a magnetic force on it $F_{\text{mag}} = I L B$

$$F_{\text{mag}} = (1.5 \text{ A})(0.10 \text{ m})(1.2 \text{ T}) = 0.18 \text{ N (to the right)}$$

To keep it moving at constant velocity, the external force must be 0.18 N to the left.

(e) $W = F \Delta x$ in 1 s $\Delta x = v \Delta t = (5.0 \frac{\text{m}}{\text{s}})(1.0 \text{ s}) = 5 \text{ m}$

$$W = (0.18 \text{ N})(5.0 \text{ m}) = 0.90 \text{ J (same as energy dissipated in circuit).}$$

⑤ No emf is produced in the top and bottom sides of the loop.

When the right-hand end enters the field region

$$\text{emf} = vBL = (1.0 \text{ m/s})(2.0 \text{ T})(0.04 \text{ m}) = 0.08 \text{ V}$$

+ charges would move up, so the current is CCW.

$$I = \text{emf}/R = \frac{0.08 \text{ V}}{16 \Omega} = 0.005 \text{ A}$$

When the left-hand edge enters the field (when $x = 10 \text{ cm}$) an opposite emf is produced in the left side, so the net current is zero.

When the right-hand edge leaves the field region (at $x = 15 \text{ cm}$), only the emf in the left side remains, so there is a clockwise current of 0.005 A , until the left side leaves the field ($x = 25 \text{ cm}$) when $I = 0$.

$$P = \frac{\Delta E}{\Delta t} = I^2 R = (0.005 \text{ A})^2 (16 \Omega) = 4.0 \times 10^{-4} \text{ W}$$

$$F_{\text{mag}} = ILB = (0.005 \text{ A})(0.04 \text{ m})(2.0 \text{ T}) = 4.0 \times 10^{-4} \text{ N}$$

The force is to the ~~left~~ ($\vec{I} \times \vec{B}$ dir) when the loop is entering the field, so the external force must be to the right.

As the loop is leaving the field, the magnetic force on the left side is still to the left, so the external force is to the right.

