PHYSICS II Problem Set 6

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Problem 1

Solution

We may discuss the electric force and magnetic force separately.

For the electric force

$$ma_E = -qE_0 \tag{1}$$

where a_E is the translational acceleration along -x-axis.

Hence the change of velocity caused by electric field is

$$v_E(t) = \left(-\frac{qE_0}{m}t, 0, 0\right) \tag{2}$$

For the magnetic force

$$qv \times B = m\omega^2 R \tag{3}$$

where R is the radius of circular motion.

Hence the change of velocity caused by magnetic field is

$$v_B(t) = (v_{y_0}\cos\omega t, v_{y_0}\sin\omega t) \tag{4}$$

where $\omega = \frac{B_0 q}{m}$

Hence the velocity of the particle is

$$v(t) = v_1(t) + v_2(t) = \left(v_{x_0} - \frac{qE_0}{m}t, v_{y_0}\cos\frac{B_0 q}{m}t, v_{y_0}\sin\frac{B_0 q}{m}t\right) \tag{5}$$

Integrate Eq.(5)

$$x(t) = \int_{x(0)}^{x(t)} v(t)dt = \left(v_{x_0}t - \frac{qE_0}{2m}t^2, \frac{mv_{y_0}}{B_0 q}\sin\frac{B_0 q}{m}t, -\frac{mv_{y_0}}{B_0 q}\cos\omega t\right) \tag{6}$$

Problem 2

Solution

1.

$$I = JA = Jwh \tag{7}$$

$$F = Il \times B \tag{8}$$

$$\Delta p = \frac{F}{wh} \tag{9}$$

Hence

$$\Delta p = JlB \tag{10}$$

2. Derived from (a)

$$J = \frac{\Delta p}{Bl}$$

Plug in the data

$$J = \frac{101.325 \times 10^3}{2.2 \times 35 \times 10^{-3}} = 1.3 \times 10^6 \ [A/m^2]$$

Problem 3

Solution Differential equation

$$dF = Idl \times B \tag{11}$$

Hence

$$F = \int_{\text{plane wire}} Idl \times B = Iw \times B \tag{12}$$

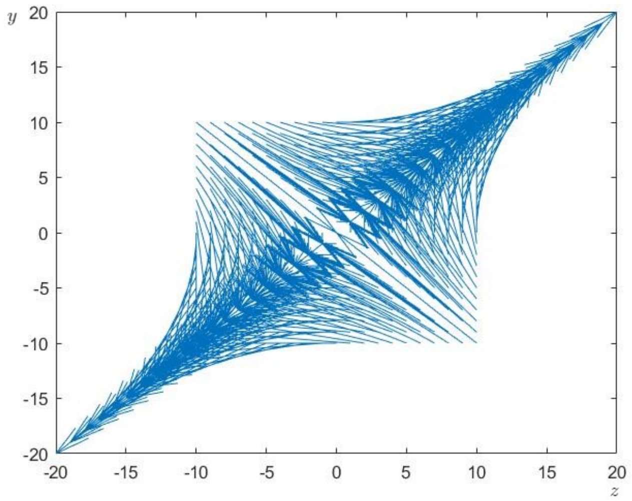
Namely, as for the magnitude

$$F = IBw \tag{13}$$

where the direction of the force is related to the direction of current. If the current is clockwise, the force points upwards while if the current is counter-clockwise, the force points downwards.

Problem 4

Solution



(a)

Figure 1: The magnetic field lines in the yz-plane

(b)

$$dF = IdlB \tag{14}$$

For the lower wire, since both y and z are equal to zero, there is no magnetic field, thus $F = 0$.

For the left wire, $z = 0$, hence

$$F = I\frac{B_0}{L}\int_0^L y\,dy = \frac{ILB_0}{2} \tag{15}$$

For the upper wire, $z = 0, y \equiv L$, hence

$$F = ILB_0 \tag{16}$$

For the right wire, $z = 0$, analogous to the left wire

$$F = -\frac{ILB_0}{2} \tag{17}$$

(c) Add all the force appearing in (b)

$$F_{\text{total}} = ILB_0 = (0, ILB_0, 0) \tag{18}$$

Problem 5

Solution

(a)

$$F = \int_\Sigma IdlB = \oint IdlB = IB\oint dl = 0 \tag{19}$$

(b)

Problem 6

Solution

(a)

$$T = \frac{2\pi R}{v} = \frac{2\pi \times 5.3 \times 10^{-11}}{2.2 \times 10^6} = 1.5 \times 10^{-16}\ [s] \tag{20}$$

(b)

$$I = \frac{e}{T} = 1.1 \times 10^{-3}\ [A] \tag{21}$$

(c)

$$\mu = (IA)\hat{n} = I\pi R^2 = 9.7 \times 10^{-24}\hat{n}\ [Am^2] \tag{22}$$