Week 18 20.26

particle (dust?), $q = 23\,\mu C$, $m = 1.3 \times 10^{-16}$ kg ; speed $v_0 = 2.0 \times 10^{3}\ \frac{m}{s}$

$\vec{v}$ is in x-y plane : $\vec{v} = v_x \hat{\imath} + v_y \hat{\jmath}$

$\vec{B} = B_0 \hat{k}$ with $B_0 = 0.88$ T (= 880 mT)

Particle circles in the xy plane

a) $R_{circle} = ?$ b) $T = ?$ period

c) particle is parallel to $+y$ @ $t=0$; is motion CW or CCW as viewed from above the z-axis ?

Solution.

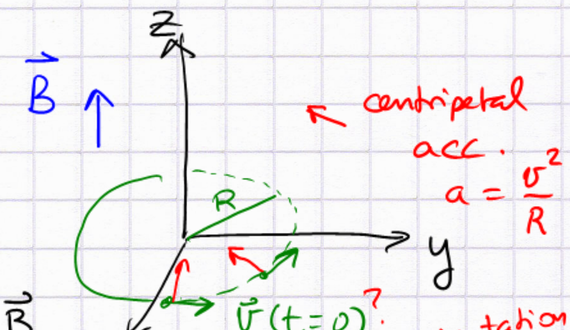
$$\frac{mv^2}{R} = qvB$$

centripetal acc from magnetic force

$\vec{F}_M = q\,\vec{v} \times \vec{B}$

↑ perp. to $\vec{v}$ and $\vec{B}$.

$$R = \frac{mv}{qB}$$



does this orientation work? It would if q was negative

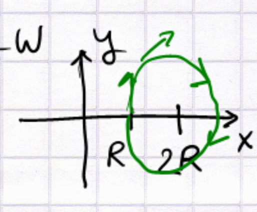
The period T from : $v = \frac{2\pi R}{T}$ $\therefore T = \frac{2\pi R}{v} = \frac{2\pi m}{qB}$

c) $\vec{F}_M = q\,\vec{v} \times \vec{B}$ for $q > 0$:

suppose @ $t=0$ $v_x(0) = 0$ and $v_y(0) = v_0$ (as shown)

$$\vec{F}_M = \begin{vmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ v_x & v_y & v_z \\ B_x & B_y & B_z \end{vmatrix} = \begin{vmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ 0 & v_0 & 0 \\ 0 & 0 & B_0 \end{vmatrix} = \hat{\imath}\, v_y B_0$$

This is not centripetal for $v_y > 0$ towards the origin, but towards $(x_0 + R, 0, 0)$. Viewed from above : motion is CW



a) $R = \frac{1.3 \times 10^{-16} \cdot 2.0 \times 10^{3}}{2.3 \times 10^{-5} \quad 0.88} = 1.28 \times 10^{-8}$ m ; b) $T = 4.0 \times 10^{-11}$ s

20.46 Long straight wire ; $I = 100$ A (a lot!) . Inside a $\vec{B}$ with $B = 10$ T (a lot!) . Yet $F_{\text{on wire}} = 0$. How?

Solution.

The force on a current-carrying wire is derived from

$\vec{F}_M = q\,\vec{v} \times \vec{B}$ using $q \to \Delta Q = I\,\Delta t$

$v = \dfrac{L}{\Delta t}$ (L = segment containing ΔQ)

$F_{\text{on wire}} = I\,L\,B \sin\vartheta$ (Eq. 20.11)

will vanish (even though I, B are large)

when $\sin\vartheta = 0$

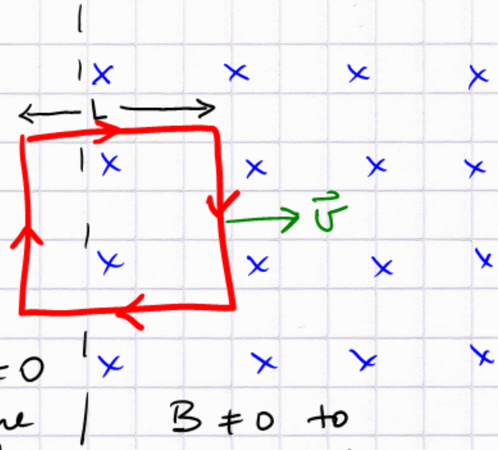
The wire is force-free for $\vartheta = 0$ or π (180°)

i.e., when I and B are aligned (or counter-aligned)

parallel or anti-parallel.

20.56

Square current loop moves right



uniform $\vec{B}$ into the plane

$L = 0.25$ m

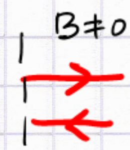
$I = 4.5$ A CW

$B = 2.5$ T

a) direction of $\vec{F}_M$ on loop? b) $|\vec{F}_M| = ?$ c) $\vec{v} \to -\vec{v}$

Solution.

Consider the horizontal pieces first:
(those immersed in $\vec{B}$)



$\uparrow \vec{F}_M$ from $q\vec{v}\times\vec{B}$
$\downarrow \vec{F}_M$
NOT $\vec{v}$ but $L/\Delta t$

Since the loop is solid these forces will cause some stress on the physical loop, but cancel.

$\downarrow \vec{F}_M \rightarrow$ is inside the $\vec{B}$ field: By RH rule $\vec{F}_M$ is to the right

$\therefore$ $\vec{v}$ will increase, but when the loop is completely immersed $F_{net} \to 0$ since $\vec{F}_M$ will cancel the force.

b) $F_M = |\vec{F}_M| = I L B = 0.25 \cdot 4.5 \cdot 2.5 = 2.8$ N

c) The velocity $\vec{v} \longrightarrow$ is not relevant in this problem (really? doesn't it change the charge flow?)

For both orientations $\vec{v}$ $\rightleftarrows$ $\vec{F}_M$ is to the right!

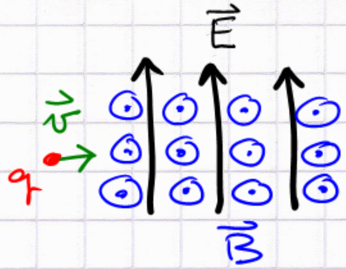
isn't the current loop eventually a blob of charge moving on a circle?

NO, the loop is NEUTRAL!

$\vec{B}$ attracts our loop: $\vec{B}_{loop}$ is into the plane for our current direction!

20.62 Velocity selector

can q go straight through?



when v_0 is right $q\vec{E}$ and $q\vec{v}\times\vec{B}$ can cancel!

$E = 500 \frac{V}{m}$, $B = 0.25T$

a) protons : $v_{sel} = ?$

b) Ca^{2+} ions $v_{sel} = ?$

c) try for F^- ions ?

Solution.

a) protons : $\vec{E}$ accelerates up. $q\vec{v}\times\vec{B}$ is down

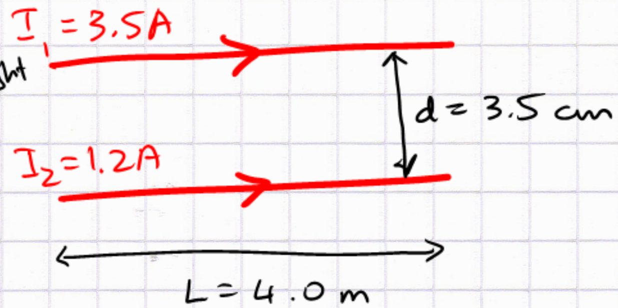
$|F_E| = |F_M|$ $\therefore$ $qE = q v_{sel} B$ $v_{sel} = \frac{E}{B} = \frac{500}{0.25} \rightarrow$ 2.0×10^3 m/s

b) charge and mass do not appear $\therefore$ v_{sel} the same

c) since the charge of the particles doesn't matter, it will select F^- ions, as well, for $v_{sel} = 2.0\times10^3 \frac{m}{s}$

20.70

parallel, straight wires



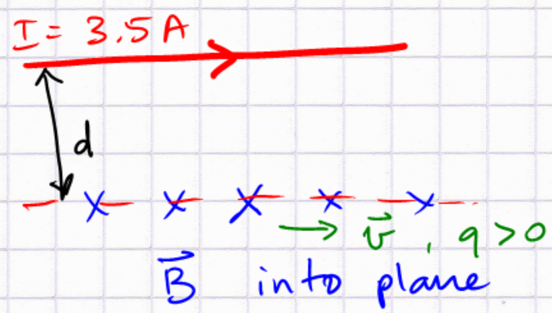
a) $F_{\text{on wire}} = ?$

b) attractive / repulsive?

c) → antiparallel currents?

Solution.

Consider $\vec{F}_{\text{on bottom wire}}$ due to $\vec{B}_{\text{from top wire}}$



RH rule:

$\vec{F}_{\text{on bottom wire}}$ is up (towards top wire)

(answers (b), by the same argument the top wire is pushed down).

a) $F = ILB$

$$B_{\text{from top wire}} = \frac{\mu_0 I_1}{2\pi d} \rightarrow 2.0 \times 10^{-5}\,T$$

.035 m!

$$\mu_0 = 4\pi \cdot 10^{-7}\,\frac{Tm}{A}$$

$$F_2 = (1.2\,A)(4.0\,m)(2.0 \times 10^{-5}\,T) = 9.6 \times 10^{-5}\,N$$

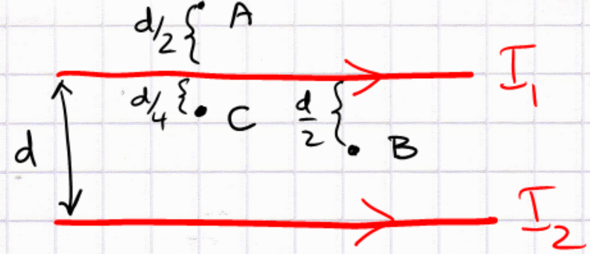
Now calculate F_1! It has to be the same magnitude (3rd law, action = reaction)

It is the same, since combining: $F_{\text{on}\,1} = I_1 L B_{\text{from}\,2}$

$$= I_1 L I_2 \frac{\mu_0}{2\pi d}$$

c) by the RH rule: forces change direction, become repulsive.

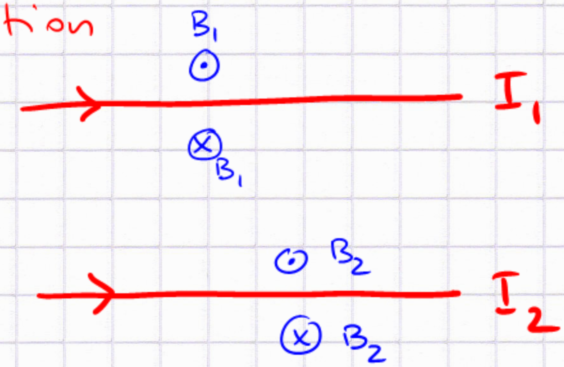
20.80



find ratios I_1/I_2 such that $B_m = 0$ @ A, B, C

dependence on d?

Solution



fields oppose each other in between the wires, add up on the outside

∴ outside regions: opposite currents required; inside region: parallel I_1 & I_2

a) A is $d/2$ from I_1 and $3d/2$ from I_2

$$B_A = \frac{\mu_0}{2\pi}\left[\frac{I_1}{d/2} + \frac{I_2}{3d/2}\right] \quad \therefore \quad 2I_1 = -\frac{2}{3}I_2 \quad \therefore I_2 = -3I_1$$

b) B $\quad B_B = \frac{\mu_0}{2\pi}\left[\frac{I_1}{d/2} - \frac{I_2}{d/2}\right]$, direction: into the plane $\quad \therefore I_1 = I_2$

c) C $\quad B_C = \frac{\mu_0}{2\pi}\left[\frac{I_1}{d/4} - \frac{I_2}{3d/4}\right] \quad \therefore \quad I_2 = 3I_1$

The actual distance d does not matter, since it drops out of the calculations.