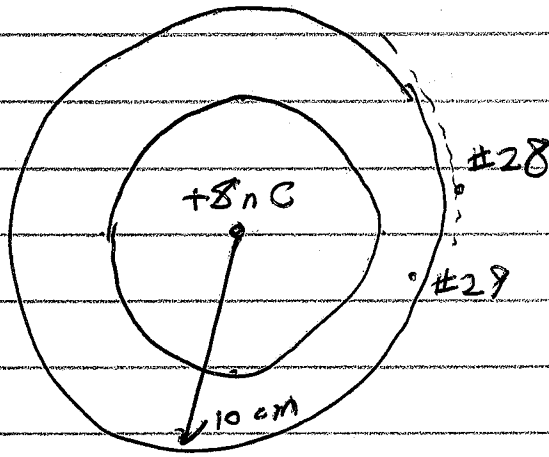
① Phys 2426 2016-10-04 Lec 12

#28/29

Metal shell

$q_{shell} = +5\,nC$



#28: Spherical Gauss's Law

$$\cancel{4\pi} r^2 E = \cancel{4\pi} k\, Q_{enc}$$

$$E = \frac{k Q_{enc}}{r^2} = \frac{k(13\,nC)}{(0.10)^2}$$

#29: $E = 0$ in metal

$$\left.\begin{array}{l} q_{inner} = -8\,nC \\ q_{outer} = 13\,nC \end{array}\right\} q_{shell} = 5\,nC$$

~~#19/20~~

⊕

$qE = mg$

$\uparrow$ now know E

$E = 4\pi k \sigma$

or

$E = 2\pi k \sigma$

Lone Surface Charge

$\uparrow E = 2\pi k\sigma \uparrow$

σ

$\downarrow E = -2\pi k\sigma \downarrow$

Surface Charge on Metal

$\uparrow E = 4\pi k\sigma \uparrow$

$E = 0$

Pair of surface charges

$\uparrow E = 2\pi k(\sigma_T + \sigma_B) \uparrow$

σ_{Top}

$E = 2\pi k(\sigma_B - \sigma_T)$

σ_{Bot}

$\downarrow E = -2\pi k(\sigma_T + \sigma_B) \downarrow$

$\uparrow E = 4\pi k\sigma$

$\sigma_T = \sigma$

$\sigma_B = \sigma$

$\downarrow E = -4\pi k\sigma$

$E = 0$

Effects of Magnetism

- Force on a charge $\vec{F} = q\vec{v} \otimes \vec{B}$
- Force on a current $\vec{F} = I\vec{l} \otimes \vec{B}$
- Torque on a loop $\vec{\tau} = NI\vec{A} \otimes \vec{B}$

$\otimes$ = times symbol for cross product

Cross Product Methods

Result $= \vec{A} \otimes \vec{B}$

Magnitude $= AB \sin\theta$

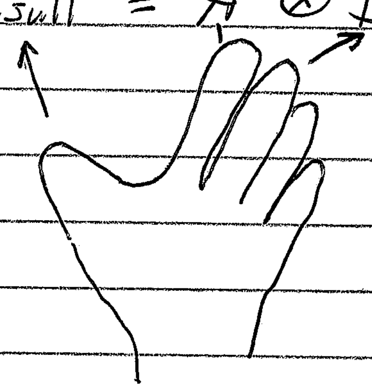
θ = Angle between $\vec{A}$ and $\vec{B}$

$\sin\theta$ = strong when $\vec{A} \perp \vec{B}$

$\sin\theta = 0$ when $\vec{A} \parallel \vec{B}$ or $\vec{A} \parallel -\vec{B}$

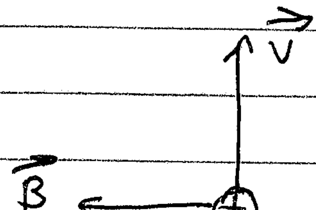
RHR for cross products

Result $= \vec{A} \otimes \vec{B}$



④

Ex: ⊕ charge moving in $+\hat{y}$.
$\vec{B}$ points in $-\hat{x}$.

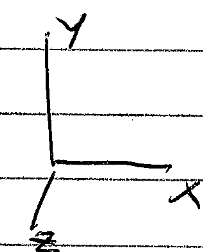


$\vec{F} = q\vec{v} \otimes \vec{B}$

Thumb = $\vec{v} \times \vec{B}$ = "out" = $+\hat{z}$

Force is "out", $+\hat{z}$.

Analytic Cross Product



$\hat{x} \otimes \hat{y} = \hat{z}$ $\qquad$ $\hat{x} \otimes \hat{x} = 0$

Swap any 2 vectors & negate the result.

$\hat{y} \otimes \hat{x} = -\hat{z}$

$\hat{y} \otimes \hat{z} = +\hat{x}$

Cycle vectors & result stays.

$y \otimes z = x$ $\qquad$ $\hat{j} \otimes \hat{k} = \hat{\imath}$

$z \otimes x = y$ $\qquad$ $\hat{k} \otimes \hat{\imath} = \hat{j}$

Ex: proton $\vec{v} = 2\hat{\imath} - 4\hat{j}$ m/s

$\vec{B} = 2\hat{j} - \hat{k}$ T

$\vec{v} \otimes \vec{B} = (2\hat{\imath} - 4\hat{j}) \otimes (2\hat{j} - \hat{k})$

$= 4\hat{k} + (2)(-1)\underbrace{(\hat{\imath} \otimes \hat{k})}_{-\hat{j}} - (4)\cancel{(2)(\hat{j} \otimes \hat{j})}^{0} - (4)(\cancel{\times})^{-1}(\hat{\imath})$

$= \cancel{8}^{4}\hat{\imath} + 2\hat{j} + 4\hat{k}$ T·m/s

Matrix method:

$$\vec{v} \otimes \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v_x & v_y & v_z \\ B_x & B_y & B_z \end{vmatrix}$$

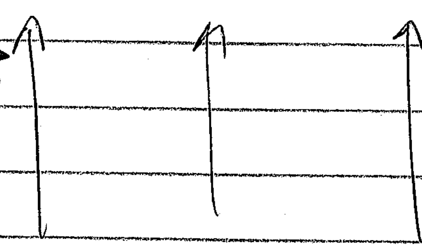
Determinant is the cross product

How could we levitate a wire?

$\vec{B}$ points North.

What direction is the current?

$\hat{y} = \vec{B}$



Gravity points toward the ground: $-\hat{z}$

Our Force points toward the sky: $+\hat{z}$

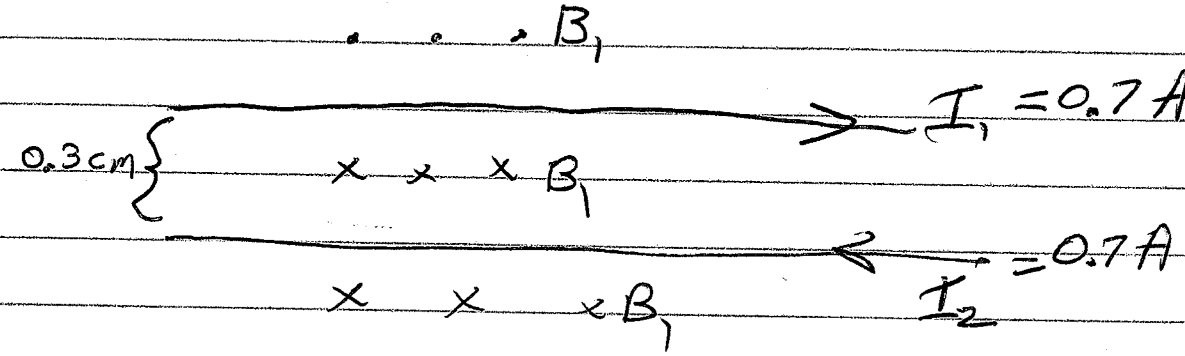
Thumb = "out of page"

Middle = "top of page"

Index = right = East = $+X$

(6)

Magnetic Force exerted by wires on each other.



Think of I_1 as the "source".

At the location of I_2:

- B_1 is <u>Into the page</u>
- $B_1 = \dfrac{\mu_0 I_1}{2\pi r} = \dfrac{(4\pi \times 10^{-7})(0.7\,A)}{2\pi\,(0.003\ m)}$

$$= 4.67 \times 10^{-5}\ T$$

Force per unit length on I_2:

- Dir is <u>Toward Bot of page</u> = Away from I_1
- $\dfrac{F}{L} = I \otimes B = (0.7)(4.67 \times 10^{-5})$

$$= 3.3 \times 10^{-5}\ N/m$$