Physics 142 - October 23, 2007

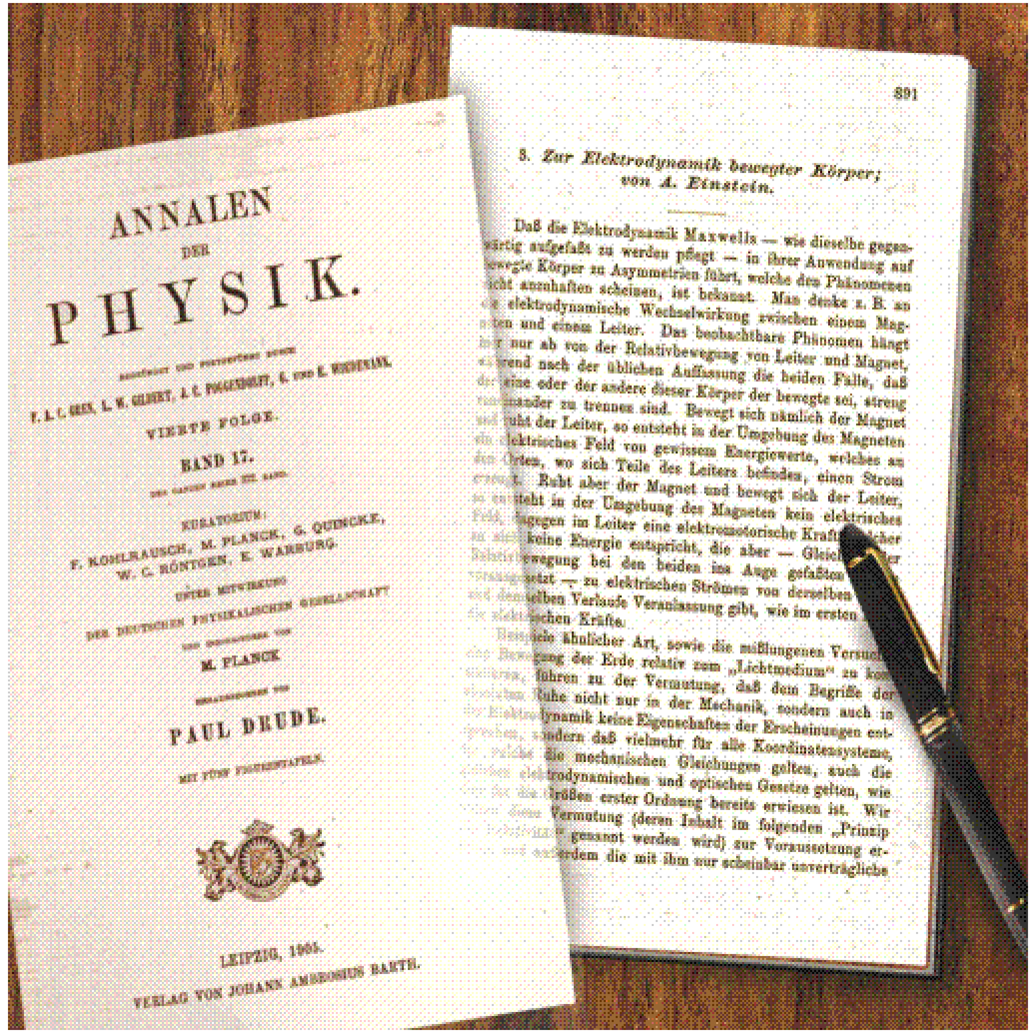
- Be sure to listen to accompanying Audio file for this lecture
- Let me know about technical difficulties
- Please e-mail me with questions
- I will assume you have covered this material (prob sets, workshops, future lectures)
- Presentation groups posted on web

Last Time

Einstein's 1905 paper on Special Relativity

"On the Electrodynamics of Moving Bodies"

Was a great year for AI



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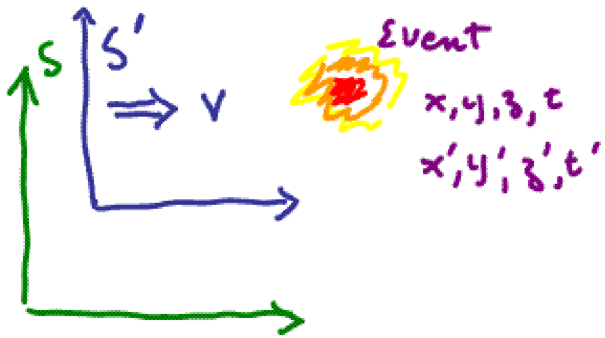
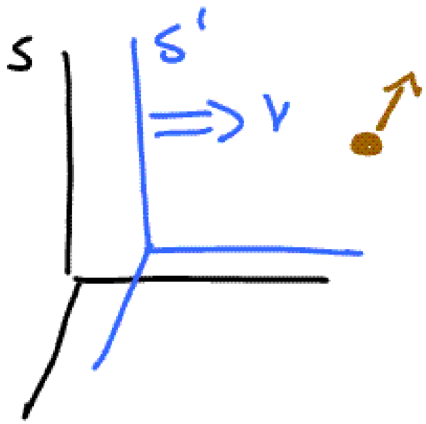


Lorentz Transformations

$$\begin{cases} x' = \gamma(x - vt) \\ y' = y \\ z' = z \\ t' = \gamma\left(t - \frac{vx}{c^2}\right) \end{cases}$$



$\vec{u}$ ≡ velocity of object in S

Relativistic velocity Transformation

$$\begin{cases} u'_x = \dfrac{u_x - v}{1 - \frac{v}{c^2} u_x} \\[2ex] u'_y = \dfrac{u_y}{\gamma\left(1 - \frac{u_x v}{c^2}\right)} \\[2ex] u'_z = \dfrac{u_z}{\gamma\left(1 - \frac{u_x v}{c^2}\right)} \end{cases}$$

proper time $\equiv \tau$ – Time measured in rest frame of event

define proper velocity $\quad \eta = \frac{dx}{d\tau} = \gamma \frac{dx}{dt} = \gamma v$

Spacetime "4-vector"

x, y, z, t

Energy-Momentum "4-vector"

p_x, p_y, p_z, E

define $p = m\eta = m\gamma v$

$E \equiv \gamma m c^2$

E, P Lorentz transforms just like x, t

$$x' = \gamma(x - vt)$$
$$y' = y$$
$$z' = z$$
$$t' = \gamma\left(t - \frac{vx}{c^2}\right)$$

$$P_x' = \gamma(P_x - vE)$$
$$P_y' = P_y$$
$$P_z' = P_z$$
$$E' = \gamma\left(E - \frac{vP_x}{c^2}\right)$$

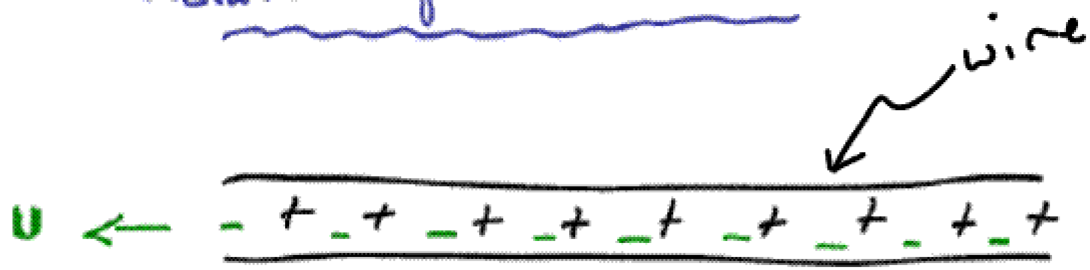
$$E = mc^2 + \frac{1}{2}mv^2 + h.o.t.$$

Relativistic Energy

$m \equiv$ "rest Mass" (CONSTANT)

Kinetic Energy

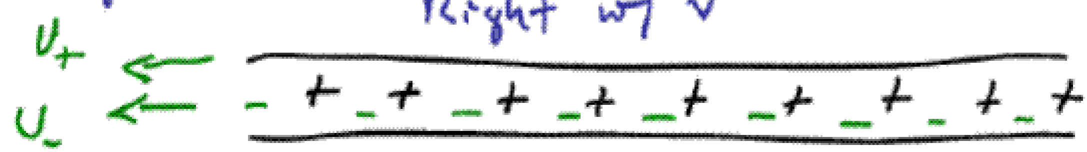
Relativity and E+M



$\lambda_- \approx \lambda_+$

A q_0 no net $\vec{E}$, No force

go to reference frame where you are Moving Right w/ v



$|U_-| > |U_+|$

$\lambda_- \not\approx \lambda_+$

$U_+ \leftarrow q_0$ now you will see an Electric force

due to perceived different λ's

... or is it an magnetic force?

Magnetism

MKS units
Tesla

Magnetic field $\equiv \vec{B}$

Lorentz Force law

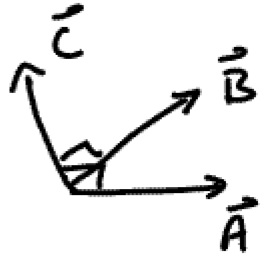
$$\boxed{\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}}$$

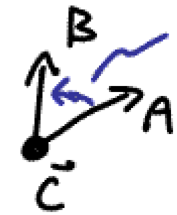
Force on charged particle
Moving w/ velocity $\vec{v}$ in
region of electric field $\vec{E}$
and Magnetic field $\vec{B}$

Cross product review

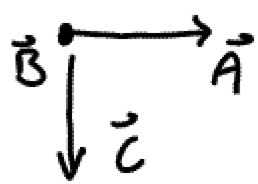
evaluate direction of $\vec{A} \times \vec{B} = \vec{C}$

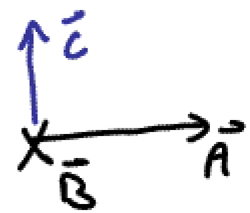
use Right hand rule





opening Angle

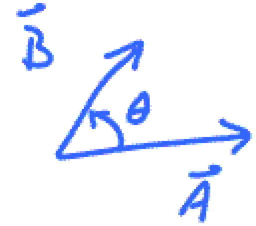




See link for video of how to find direction of cross product using Right hand rule

http://physics.syr.edu/courses/video/RightHandRule/index2.html

$$|\vec{A}\times\vec{B}| = |\vec{A}|\,|\vec{B}|\sin\theta$$



can evaluate as Determinant

opening Angle between vectors $\vec{A}$ and $\vec{B}$

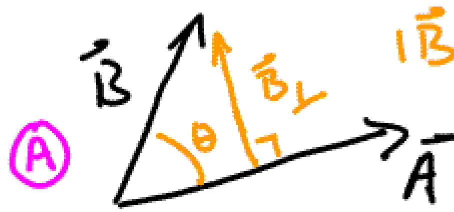
(A) $$\vec{A}\times\vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix} = \hat{i}\,(A_yB_z - A_zB_y) - \hat{j}\,(A_xB_z - A_zB_x) + \hat{k}\,(A_xB_y - A_yB_x)$$

(B)

(C)

- Cross product is a **vector**

- Cross product magnitude is product of magnitude of one vector and $\perp$ component of the other vector



$|\vec{B}_\perp| = |\vec{B}| \sin\theta$

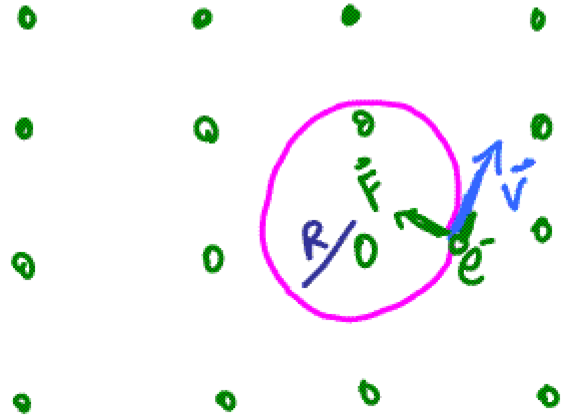
$q\vec{v}\times\vec{B}$

magnetic part of lorentz force is at right angles to $\vec{v}$ and $\vec{B}$

$\underline{\underline{\vec{F} = 0}}$

no magnetic force if $\vec{v} = 0$ or $\vec{v} \perp$ to $\vec{B}$

Region of uniform $\vec{B}$ out of screen



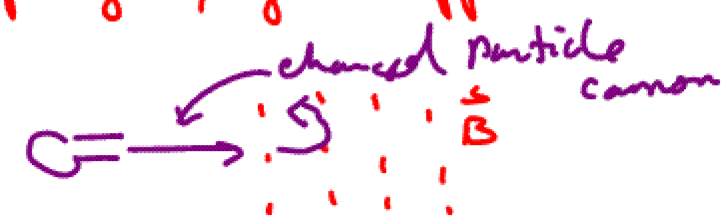
$\vec{F}_{Magnetic}$ = Centripetal force

(A) $F_c = \frac{mv^2}{R} = qvB$

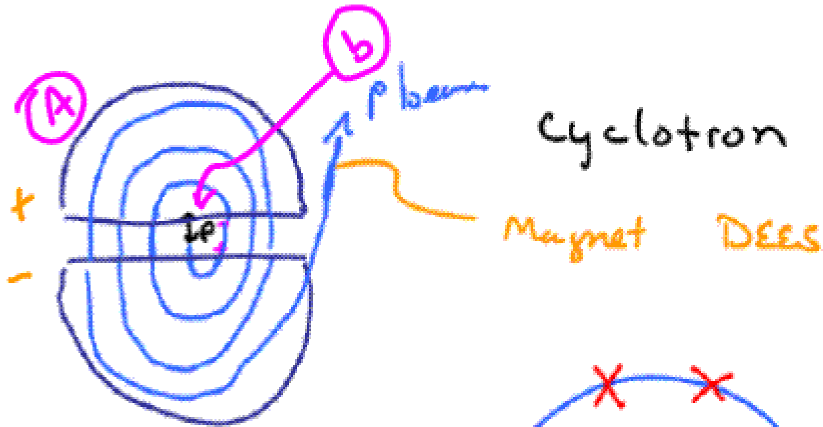
$R = \frac{mv}{qB}$ (B)

magnetic fields commonly used to control path of charged particles

Go to class website and play w/ java applet "Magnetic Fields"

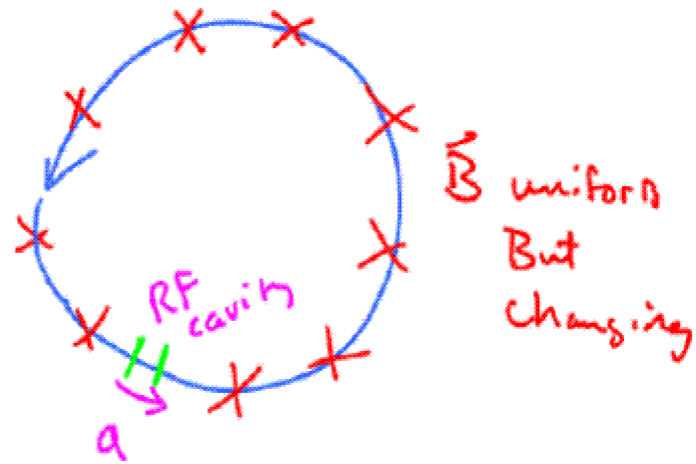


Particle Accelerators



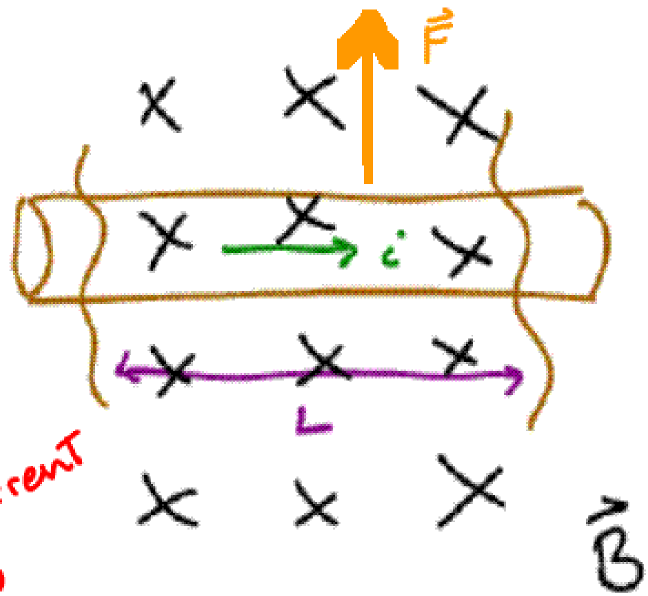
Cyclotron

Synchrotron



Current in a wire $\Rightarrow$ moving charges

expect magnetic force on current-carrying wires.



Remember direction of i is that for ⊕ current flow

Ⓐ $\vec{F}_{wire} = (q\vec{V}_d \times \vec{B})\, n A L$

charges / unit volume

charge drift velocity

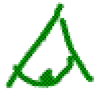
x-sectional area

Ⓑ $i = n q v_d A$

$\vec{L} = L\,(\widehat{i\ \text{direction}})$

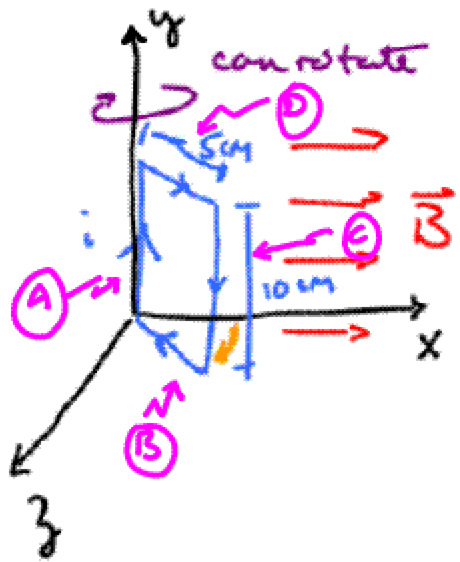
Ⓒ $\boxed{\vec{F}_{wire} = L\vec{i} \times \vec{B} \quad \text{or} \quad i\vec{L} \times \vec{B}}$

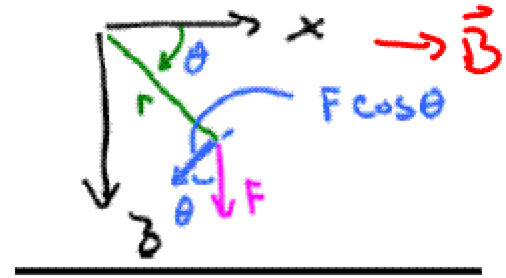
Current loop in $\vec{B}$ – what is torque about y axis ?

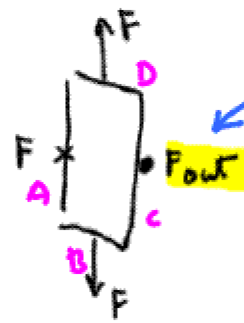


observe from this pt of view

Project in x-z plane



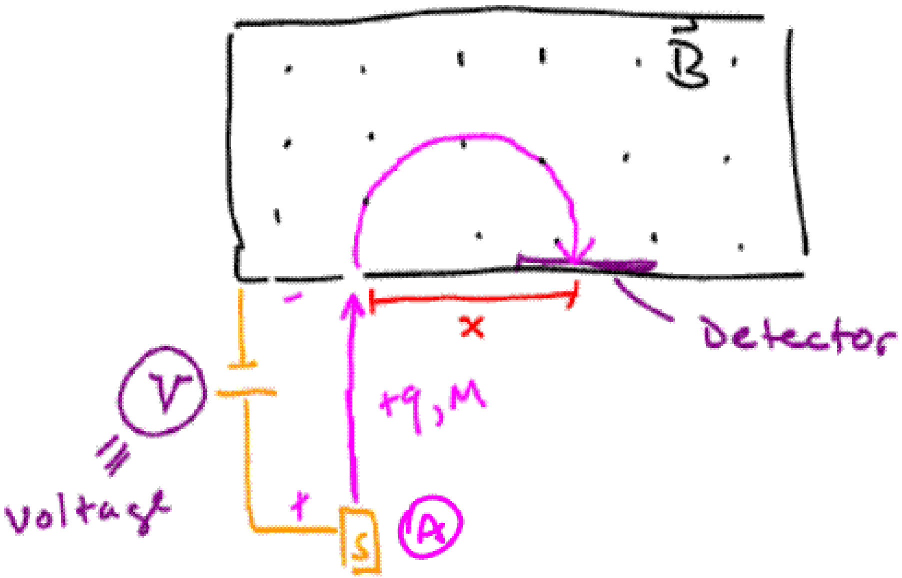




only force that matters for rotation about y

$$\vec{\tau} = \underbrace{F}_{ilB} \cos\theta \; r \left(\text{down } -\hat{y}\right)$$

Mass Spectrometer



See Magnetic fields java applet on class website

V = velocity

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

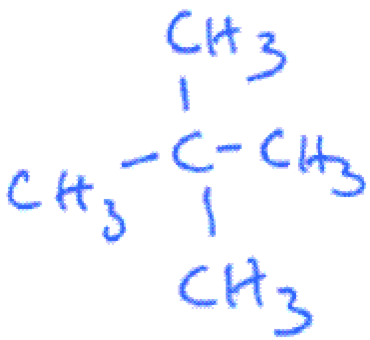
$$qvB = \frac{mv^2}{R} \qquad m = \frac{qRB}{v}$$

$$KE = +q|e|V = \frac{1}{2}mv^2$$

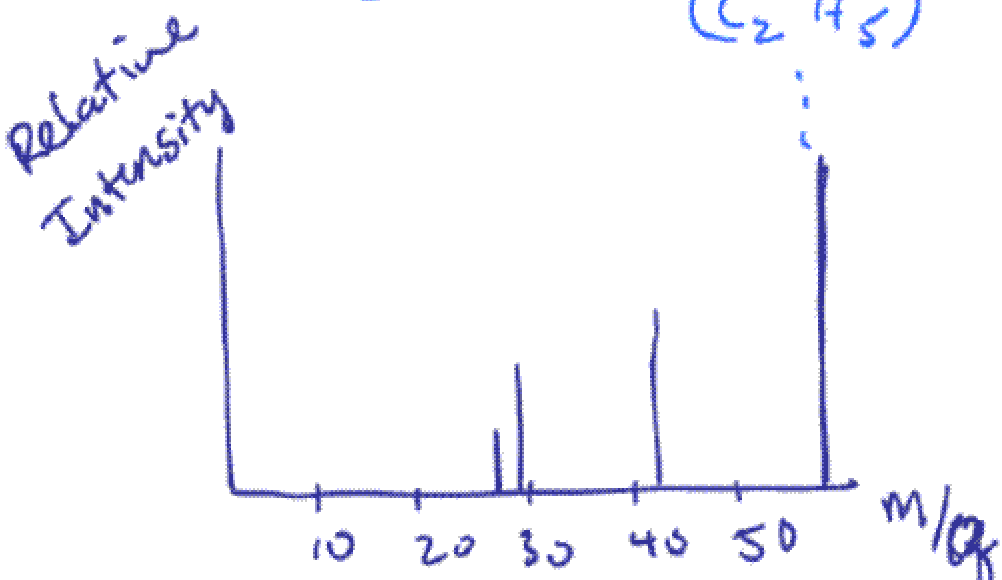
$$v = \left(\frac{2qV}{m}\right)^{1/2}$$

$x = 2R$

$$\text{(A)}\quad m = \frac{|e|q R^2 B^2}{2V} = \frac{|e|q B^2 x^2}{8V}$$



	m/q	Rel int.
$(C_4H_9)^+$	57	100
$(C_3H_5)^+$	41	41.5
$(C_2H_5)^+$	29	38.5
⋮	⋮	⋮



$\frac{m}{q}$ determined by x position