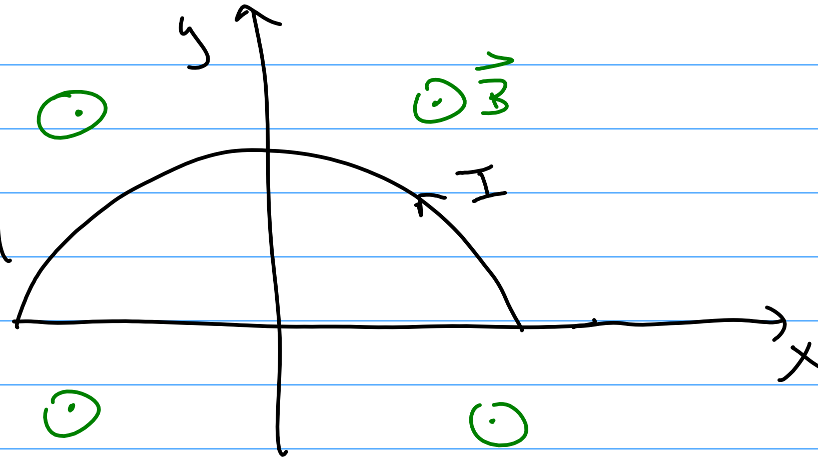
Lecture 8 Shadowitz parts of sections 1-5, 1-6, 1-7, and 3-3 may be covered.

InkSurvey question for Friday

Find $d\vec{\ell} = d\vec{r}$ needed to determine $d\vec{F}$



$F = q\, \vec{v} \times \vec{B}$ Lorentz force $\vec{F} = \int I\, d\vec{\ell} \times \vec{B}$, $d\vec{\ell} = d\vec{r}$

There are two easy ways to find $d\vec{r}$

1. $d\vec{r} = d\vec{\ell} = R\, d\varphi\, \hat{\varphi}$

$\varphi + 90 + \psi = 180$

$\psi = 90 - \varphi$

φ goes from $0 \to 2\pi$

$$\boxed{d\vec{r} = R\, d\varphi\left(-\sin\varphi\, \hat{x} + \cos\varphi\, \hat{y}\right)}$$

$\hat{\varphi} = -\cos\psi\, \hat{x} + \sin\psi\, \hat{y}$

$\hat{\varphi} = -\sin\varphi\, \hat{x} + \cos\varphi\, \hat{y}$

Method 2 $x^2 + y^2 = R^2 \Rightarrow y = \sqrt{R^2 - x^2}$

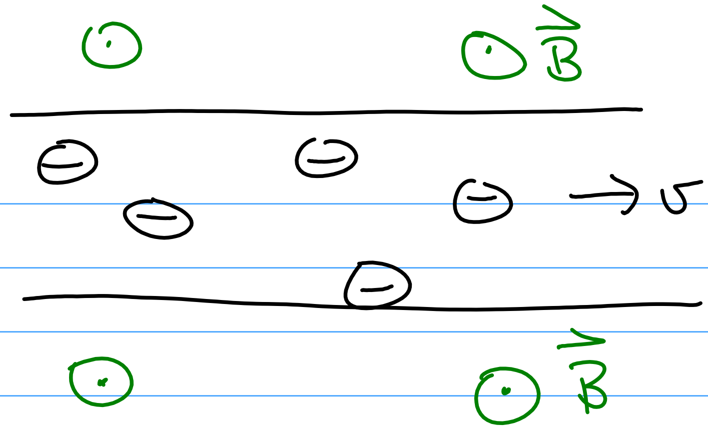
$\vec{r} = x\hat{x} + y\hat{y} = x\hat{x} + \sqrt{R^2 - x^2}\, \hat{y}$

$$\boxed{d\vec{r} = dx\, \hat{x} + \frac{1}{2}\frac{1}{\sqrt{R^2 - x^2}}(-2x\, dx)\, \hat{y}}$$

x goes from $-R$ to R

Same answer from both methods but different variables: φ or x

InkSurvey question for Friday

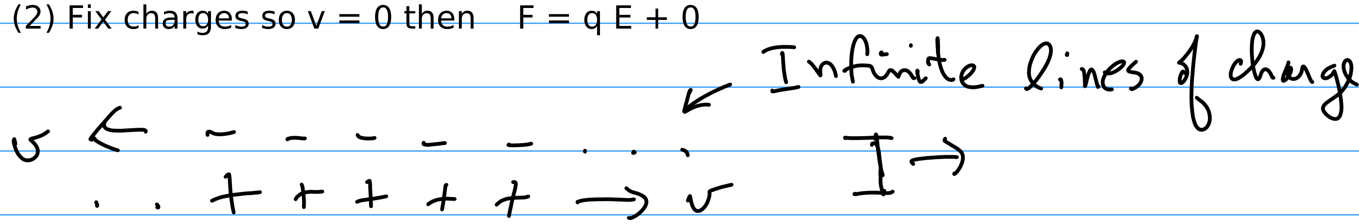


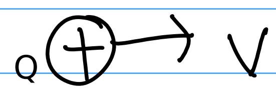
How can there be a force on a wire if the electrons are free to move?

Muddiest points:

(1) When to use Gauss's law:

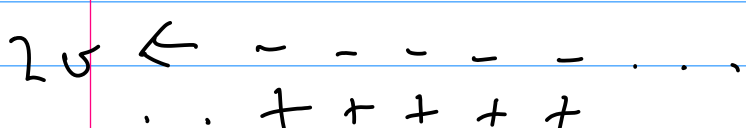
(2) Fix charges so v = 0 then F = q E + 0

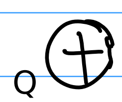




What is the force on Q?

Go to a reference frame moving to the right at speed V





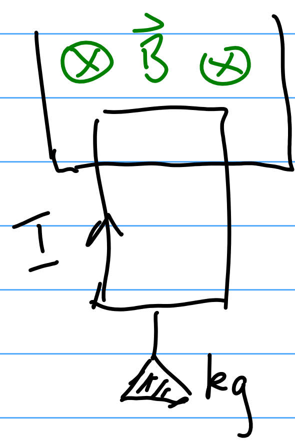
What is the force on Q?

(3) Where does the Lorentz force come from?

(4) More examples of magnetic forces on wires.

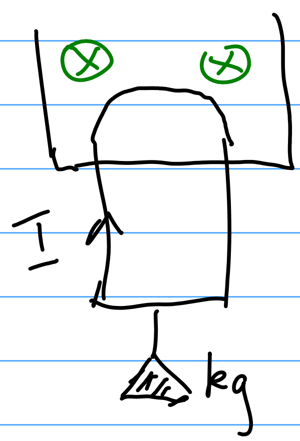
Kilogram standard is in Paris. It is the least well known of our standards.

How to make it more accurate?



$\vec{F} =$

What problems arise?



(4) B from a non-uniform current density

(5) Approximation $\dfrac{1 - v/c}{1 + v/c}$ $\quad \frac{v}{c}$ typically $\ll 1$

(6) Finding $\vec{r} \neq \vec{r}\,'$

(7) 1-D motion of charge is meant to indicate motion in line across a surface

or in a volume. Probably should be called line charge motion rather than 1-D

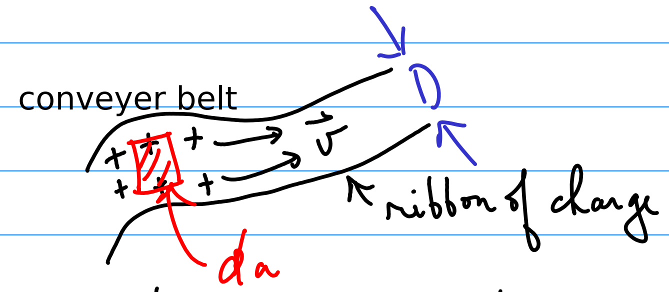
(8) Look at the solutions to the exam for feedback if you didn't get full credit.

(9) Ribbon of charge moving

$$dq = \sigma\, da$$

$$d\vec{F} = dq\, \vec{v} \times \vec{B}$$

$$= \sigma\, da\, \vec{v} \times \vec{B}$$

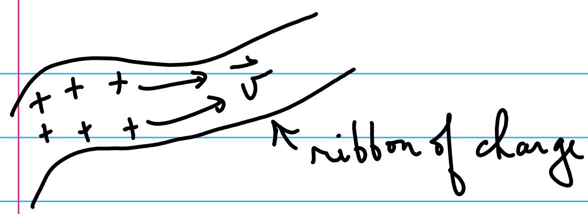


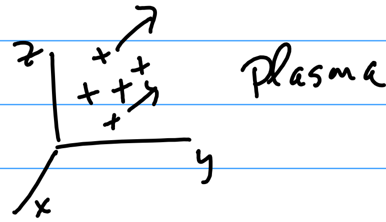
$$\sigma v = K\left(\frac{C}{m \cdot s}\right) \;:\; K D \left(\frac{C}{m^2}\frac{m}{s}\, m\right)$$

$$\frac{C}{m^2}\;\frac{m}{s}$$

What have we covered?

Calculate the force given B and the currents moving along a line, surface, or in a volume.



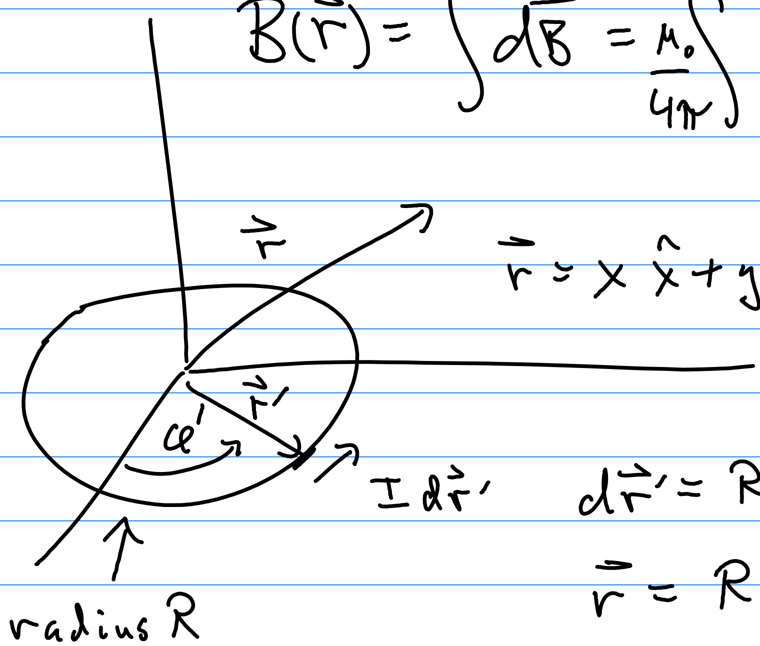


What are we going to cover?

Calculate B given currents

Law of Biot + Savart

$$\vec B(\vec r) = \int d\vec B = \frac{\mu_0}{4\pi}\int \frac{I\,d\vec r' \times (\vec r - \vec r')}{(\vec r - \vec r')^3}$$



$$\vec r = x\hat x + y\hat y + z\hat z$$

$$d\vec r' = R\,d\varphi'(-\sin\varphi'\,\hat x + \cos\varphi'\,\hat y)$$

$$\vec r = R\cos\varphi'\,\hat x + R\sin\varphi'\,\hat y$$

General result

$$\vec B(x,y,z) = \int d\vec B = \frac{\mu_0}{4\pi}\int \frac{\vec J(\vec r') \times (\vec r - \vec r')}{(\vec r - \vec r')^3}\,dx'dy'dz'$$

What is $\vec{\nabla} \cdot \vec{B}$?

$$\vec{\nabla} \cdot \frac{\mu_0}{4\pi} \int \frac{\vec{J}(\vec{r}\,') \times (\vec{r} - \vec{r}\,')}{(\vec{r} - \vec{r}\,')^3} dx' dy' dz'$$

Interpretation of divergence: a measure of how the vector function spreads out (diverges) from the point at which it is calculated. It is used to indicate a source of the vector function.

$$\vec{\nabla} \cdot \vec{E} = \rho / \epsilon_0 \qquad \vec{\nabla} \cdot \vec{J} = -\frac{\partial \rho}{\partial t} + \text{Source term}$$

The curl of a vector function is given by

$$\vec{\nabla} \times \vec{B} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ B_x & B_y & B_z \end{vmatrix} = \hat{x}\left(\frac{\partial B_z}{\partial y} - \frac{\partial B_y}{\partial z}\right) + \cdots$$

It is a measure of how much the vector B curls around the point in question.

Sprinkle pine needles on a water surface. If there is a faucet just under the surface the needles will move away from each other. They diverge and the divergence of the velocity vector function is non-zero at the point of the faucet.

If the needles are in a vortex they move in circles or curl around that point. The curl of the velocity vector function is non-zero at the point of the vortex.