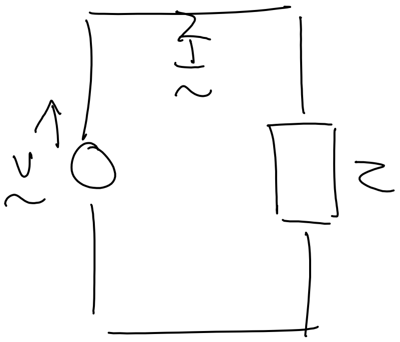
# Lecture 1

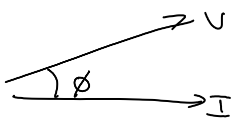
Sunday, 9 August 2009
5:11 PM

Convenor: Mr Ismat Hijazin

## Magnetic Circuits



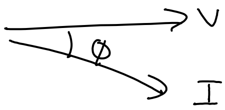

if voltage leads current
$\phi$ = +ve.

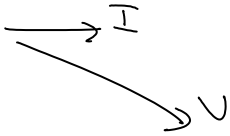



Net inductive

$\therefore$ Q = positive.

same




Q = negative
Net capacitative

$P = VI\cos\phi$ power

$Q = VI\sin\phi$ reactive power

$S = VI$ apparent power

$\tilde{S} = P + jQ$

$= VI\cos\phi + jVI\sin\phi$

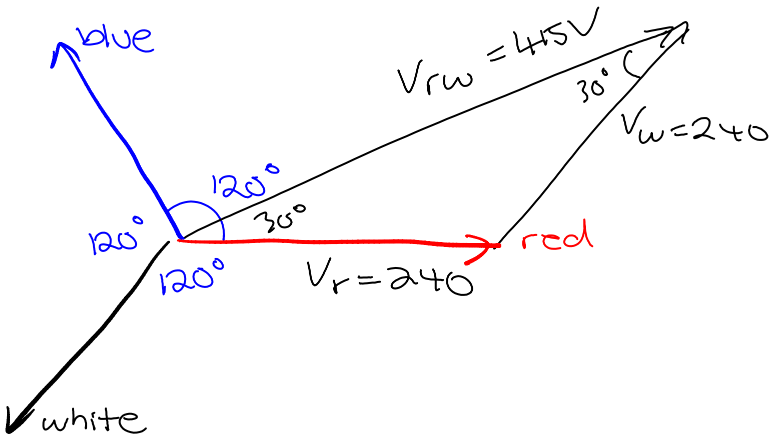
$= VI(\cos\phi + j\sin\phi)$

$= VI\,e^{j\phi}$

$= VI\angle\phi$

$\therefore \tilde{S} = \underline{V}\,\underline{I}^{*}$ complex conjugate of current.

Phases are at 120°




3-phase saves copper.

3× power → 1 additional wire.

# Magnetic Quantities

## Observations

1. A current carrying conductor (ccc) in a magnetic field has a force exerted on it.

2. There is a magnetic field associated with a ccc

3. There is a magnetic field associated with a changing electric field.

4. There is a magnetic field associated with the orbital motion of the electron around its nucleus and also with its spin

5. A changing magnetic field in the vicinity of a conductor will generate an EMF and current in the conductor.

# Introduction to $\underset{\sim}{H}$

$$V = IR \; ; \; R = \frac{\rho l}{a} = \frac{l}{\sigma A}$$

(ρ: resistivity; l: length; a: area)

$$\therefore V = I \frac{l}{\sigma A}$$

$$\frac{I}{A} = \sigma \frac{V}{l}$$

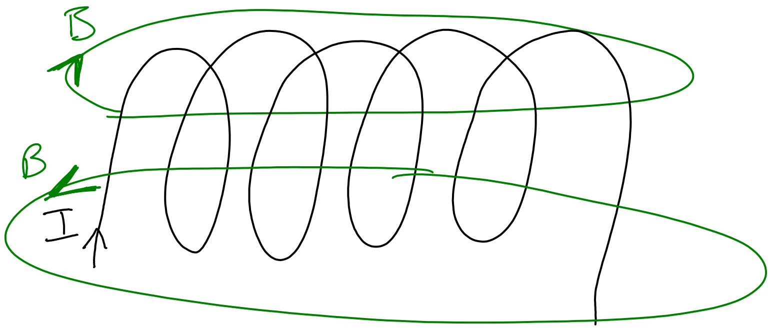
$$\underline{J} = \sigma \underline{E}$$

(J: current density; σ: conductivity; E: electric field)

For Cu $\quad \underline{J}_{cu} = \sigma_{cu} \underline{E}$

For Carbon $\quad \underline{J}_c = \sigma_c \underline{E}$

Now consider a solenoid (coil of wire) with fixed current flow $\underline{I}$




$\underline{B}$ will be different for each different material placed in the solenoid

Hence another quantity is required to describe the magnetic field intensity which is independent of the medium.

(Analogous to $\underline{E}$)

$$B = \mu H$$

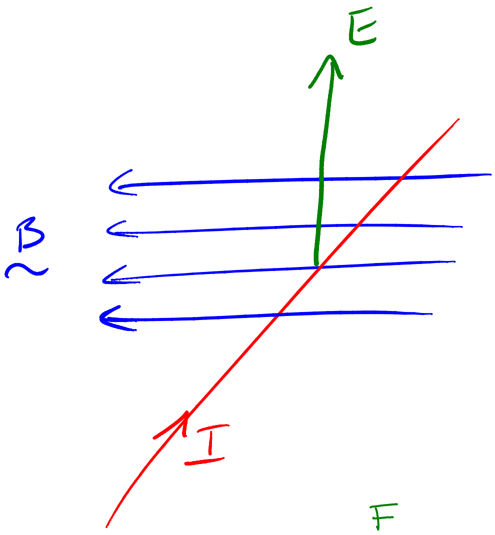
depends only on the current. (H)

$\mu_0 = 4\pi \times 10^{-7}$ H/m ($\mu$ for air)

H is the strength of the source
B is the reaction of the material to the source.

The value of B will be different for a given value of $\tilde{H}$. and depends on the material placed in the solenoid.

## Force on a CCC



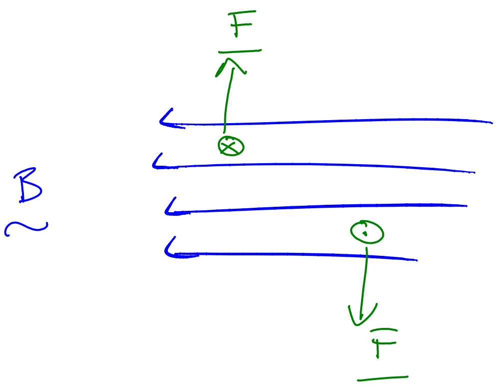

cross product

$$\delta \underline{F} = I \, \delta \underline{l} \otimes \underline{B}$$

(need to integrate)

vector cross product.

$$A \times B \neq B \times A$$
$$A \times B = - B \times A$$

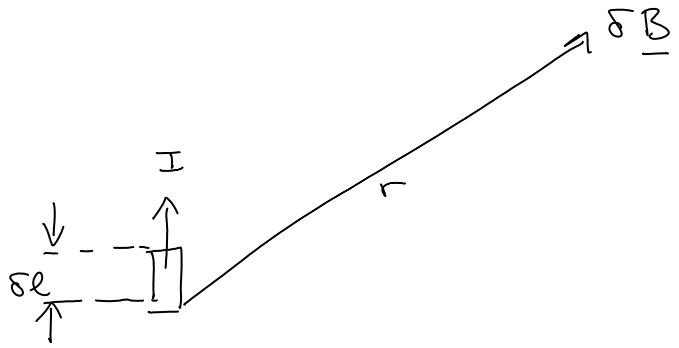



if $l$ and B are perpendicular

$$F = BIl$$

Biot Savart Law

# Biot Savart Law




$$\delta \underline{B} = \frac{\mu_0}{4\pi} \frac{I \, \delta \underline{l} \times \hat{\underline{r}}}{r^2}$$

$\underline{B}$ = magnetic field

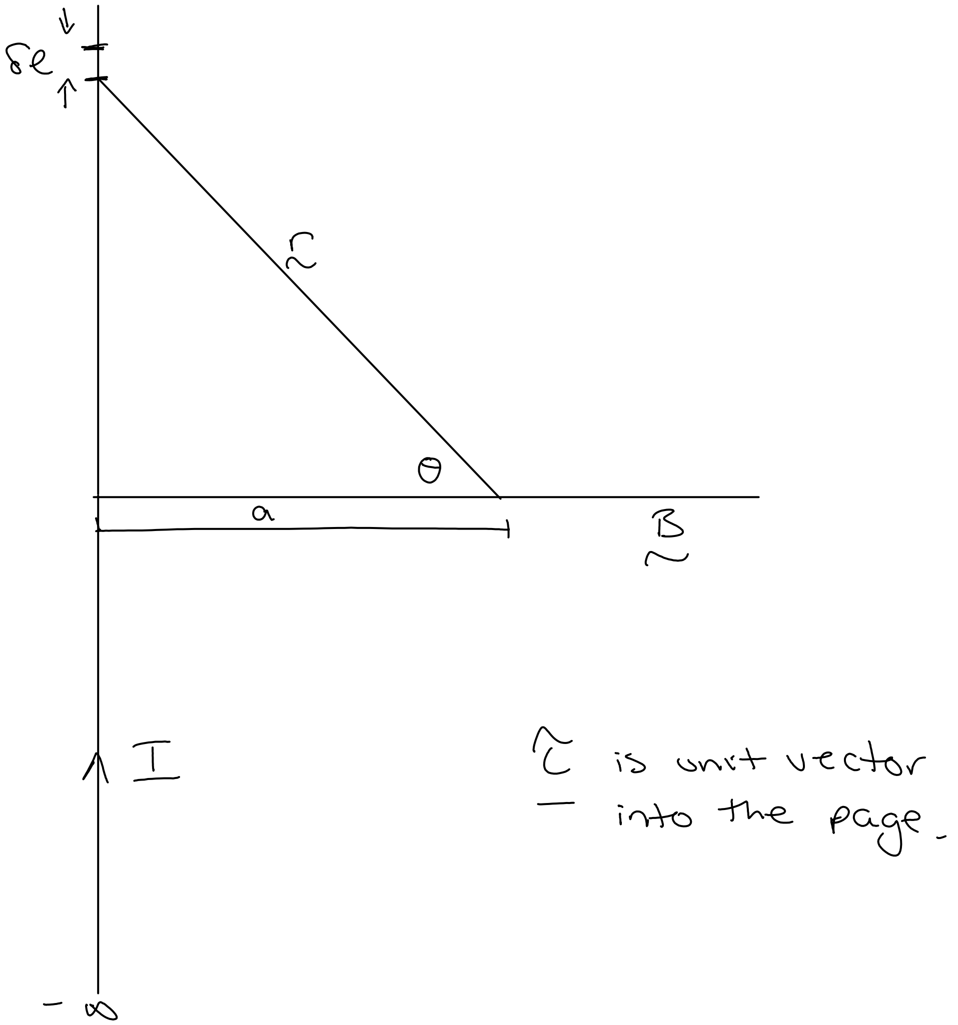
$I$ = current

$r$ = the distance from the current carrying element

$l$ = length of the CCC

## Example 1

∞




Calculate $\underset{\sim}{B}$ at 'a' from the ccc of infinite length.

$$\delta B = \frac{\mu_0}{4\pi} \frac{I \, \delta l \times \hat{r}}{r^2}$$

$$\therefore B = \frac{\mu_0}{4\pi} \int_{-\infty}^{\infty} \frac{I \, \delta l \times \hat{r}}{r^2}$$

consider $dl \times r$

$$dl \times r = dl \,.\, 1 \,.\, \sin\left(\frac{\pi}{2} + \theta\right) \hat{\underset{\sim}{\tau}}$$

$$= dl \cos\theta \, \hat{\underset{\sim}{\tau}}$$

$$r\cos\theta = a \qquad r = a\sec\theta$$

$$\tan\theta = \frac{l}{a}$$

$$\frac{dl}{d\theta} = a\sec^2\theta \quad a \times \text{ derivative of } \tan\theta$$

& @ $l = \infty \quad \theta = \frac{\pi}{2}$

$l = -\infty \quad \theta = -\frac{\pi}{2}$

$$\therefore \underline{B} = \frac{\mu_0}{4\pi}\int_{-\infty}^{\infty} \frac{I\, dl \times \hat{r}}{r^2}$$

$$= \frac{\mu_0 I}{4\pi}\int_{-\infty}^{\infty} \frac{dl\cos\theta}{a^2\sec^2\theta}\ \hat{\underset{\sim}{z}}$$

$$= \frac{\mu_0 I}{4\pi}\int_{-\pi/2}^{\pi/2} \frac{a\sec^2\theta\cos\theta\, d\theta}{a^2\sec^2\theta}$$

$$= \frac{\mu_0 I}{4\pi a}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \cos\theta\, d\theta\ \hat{\underset{\sim}{z}}$$

$$= \frac{\mu_0 I}{4\pi a}\Big[\sin\theta\Big]_{-\pi/2}^{\pi/2}\ \hat{\underset{\sim}{z}}$$

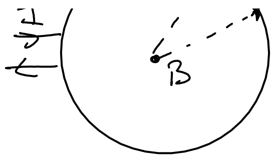
$$= \frac{\mu_0 I}{4\pi a}\big[1 - -1\big]\ \hat{\underset{\sim}{z}}$$

$$= \frac{\mu_0 I}{2\pi a}\ \hat{\underset{\sim}{z}}$$

Units of $B$ = Tesla = $(Wb/m^2)$

## Example 2


calculate $B$ at the centre




of a CCC of radius r

$$\delta B = \frac{\mu_0}{4\pi} \frac{I\, dl \times \hat{r}}{r^2}$$