Course Updates

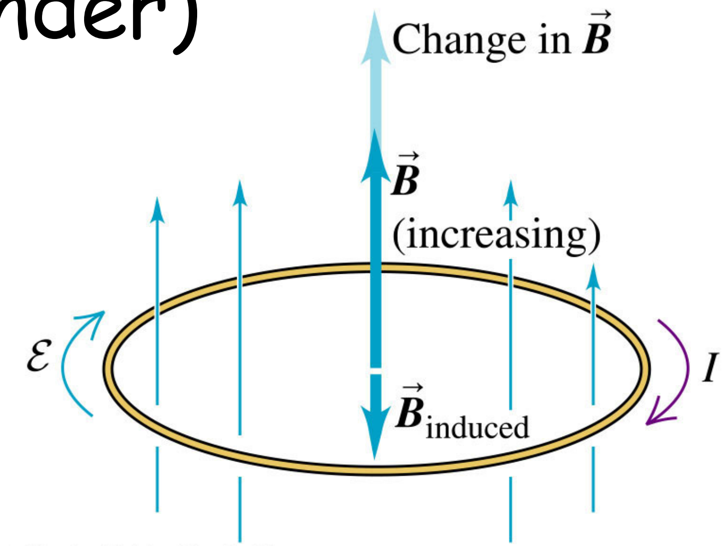
http://www.phys.hawaii.edu/~varner/PHYS272-Spr10/physics272.html

Reminders:

1) Assignment #9 → due Monday after Spring Break
2) Midterm #2 Wednesday after Break
3) Quiz # 4 today
4) Review for MT #2 Monday, March 29

Faraday's Law (reminder)

What causes current to flow in wire?
Answer: an $\vec{E}$ field in the wire.



A changing magnetic flux not only causes an EMF around a loop but an induced electric field.
Can write Faraday's Law:

$$\varepsilon = \oint \vec{E} \cdot d\vec{l} = -\frac{d}{dt}\int \vec{B} \cdot d\vec{A} = -\frac{d\Phi_B}{dt}$$

Remember for a long straight wire of length l, V = El.

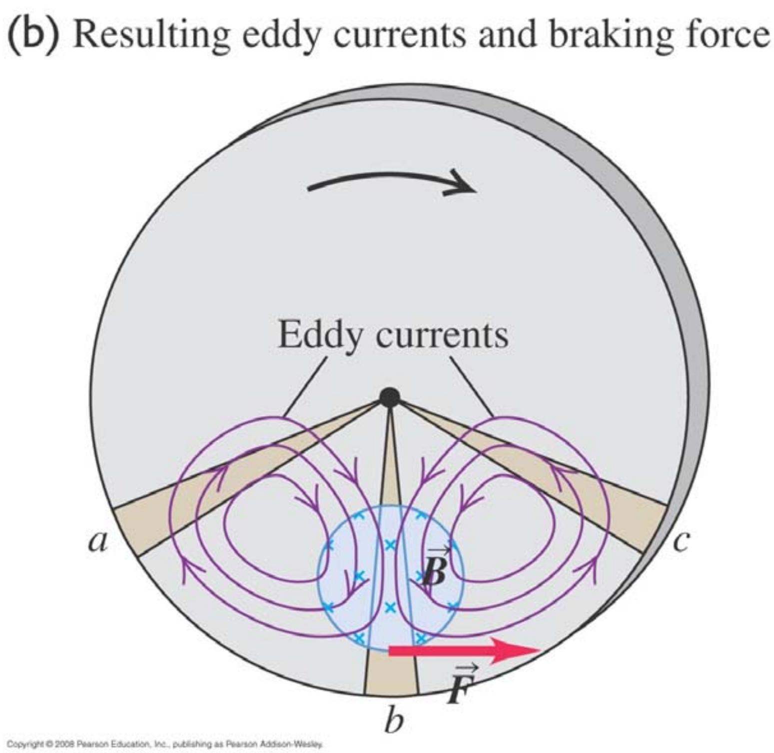
Note: For electric fields from static charges, the EMF from a closed path is always zero. Not true here.
There are two sources for electric fields!

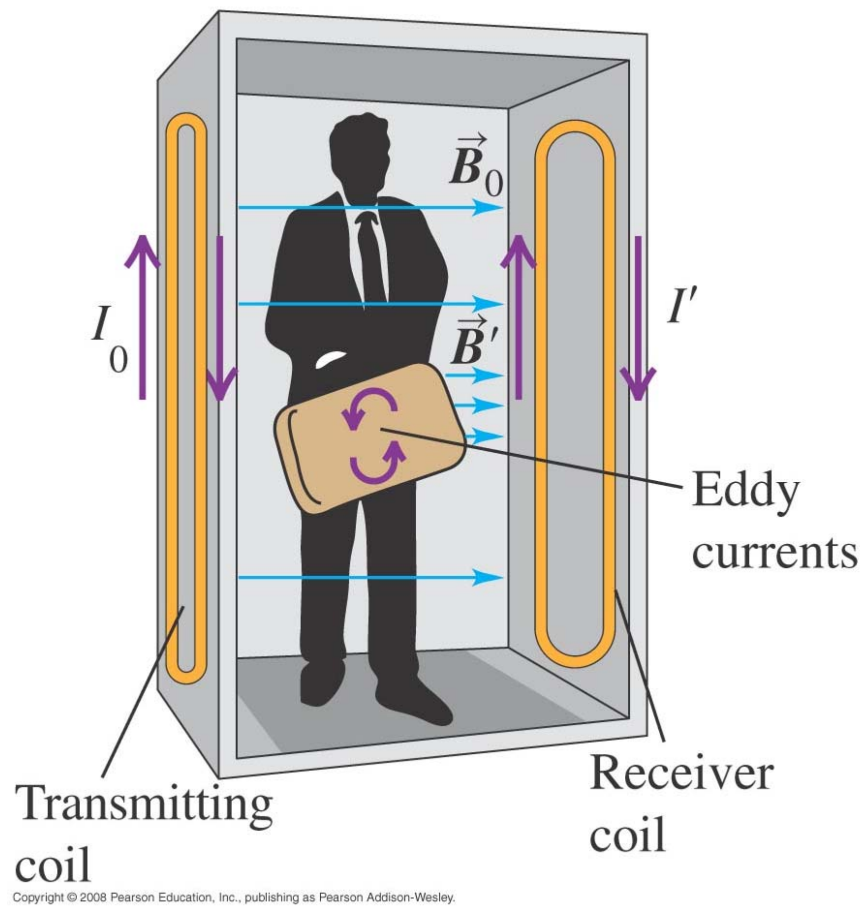
Eddy Currents

Changing magnetic fields in metal induce eddy currents, reducing strength of received B field.

Example: metal detector

Eddy currents often useful.





Maxwell's Equations (integral form)

Name	Equation	Description
Gauss' Law for Electricity	$\int \vec{E} \cdot d\vec{A} = \frac{Q}{\varepsilon_0}$	Charge and electric fields
Gauss' Law for Magnetism	$\int \vec{B} \cdot d\vec{A} = 0$	Magnetic fields
Faraday's Law	$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$	Electrical effects from changing B field
Ampere's Law	$\int \vec{B} \cdot dl = \mu_0 i$ Needs to be modified.	Magnetic effects from current + ?

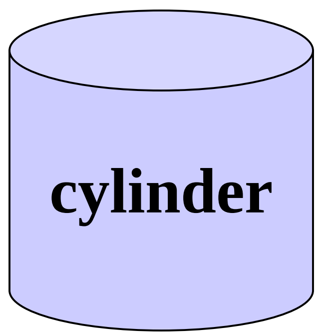
There is a serious asymmetry.

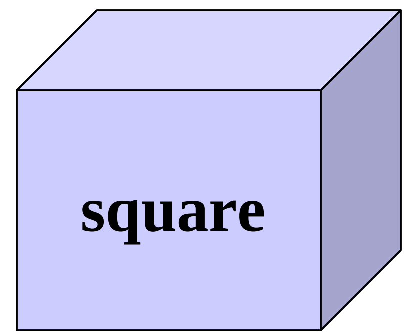
Remarks on Gauss Law's with different closed surfaces

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{enclosed}}{\varepsilon_0}$$

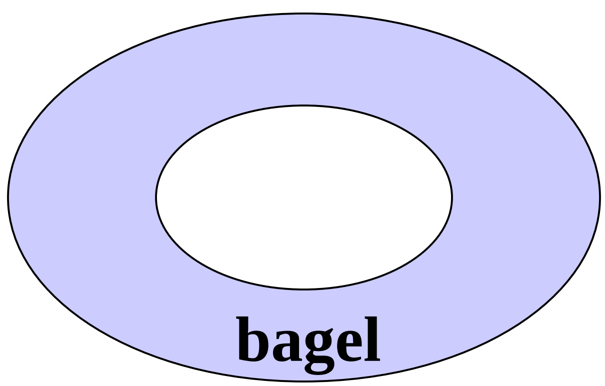
Gauss Law's works for ANY CLOSED SURFACE

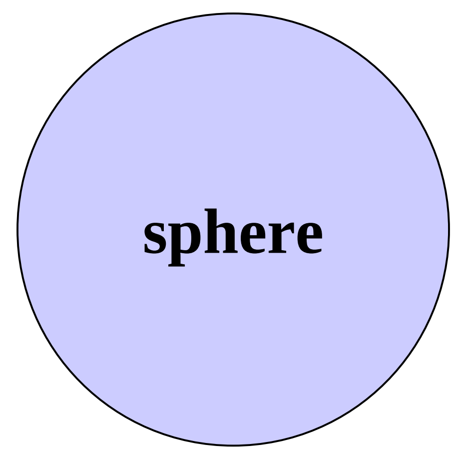
$$\oint \vec{B} \cdot d\vec{A} = 0$$





Surfaces for integration of E flux

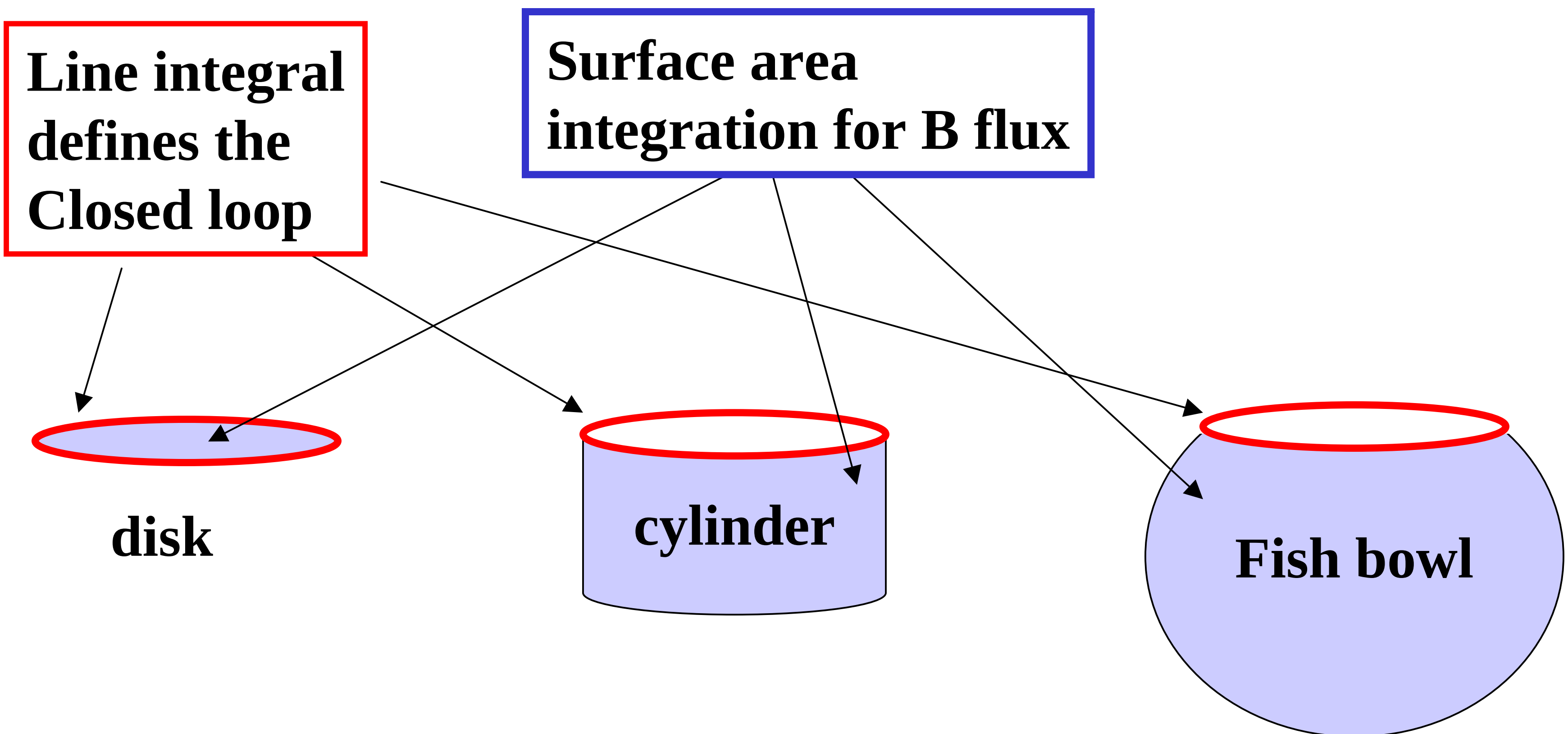




Remarks on Faraday's Law with different attached surfaces

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d \int \vec{B} \cdot d\vec{A}}{dt}$$

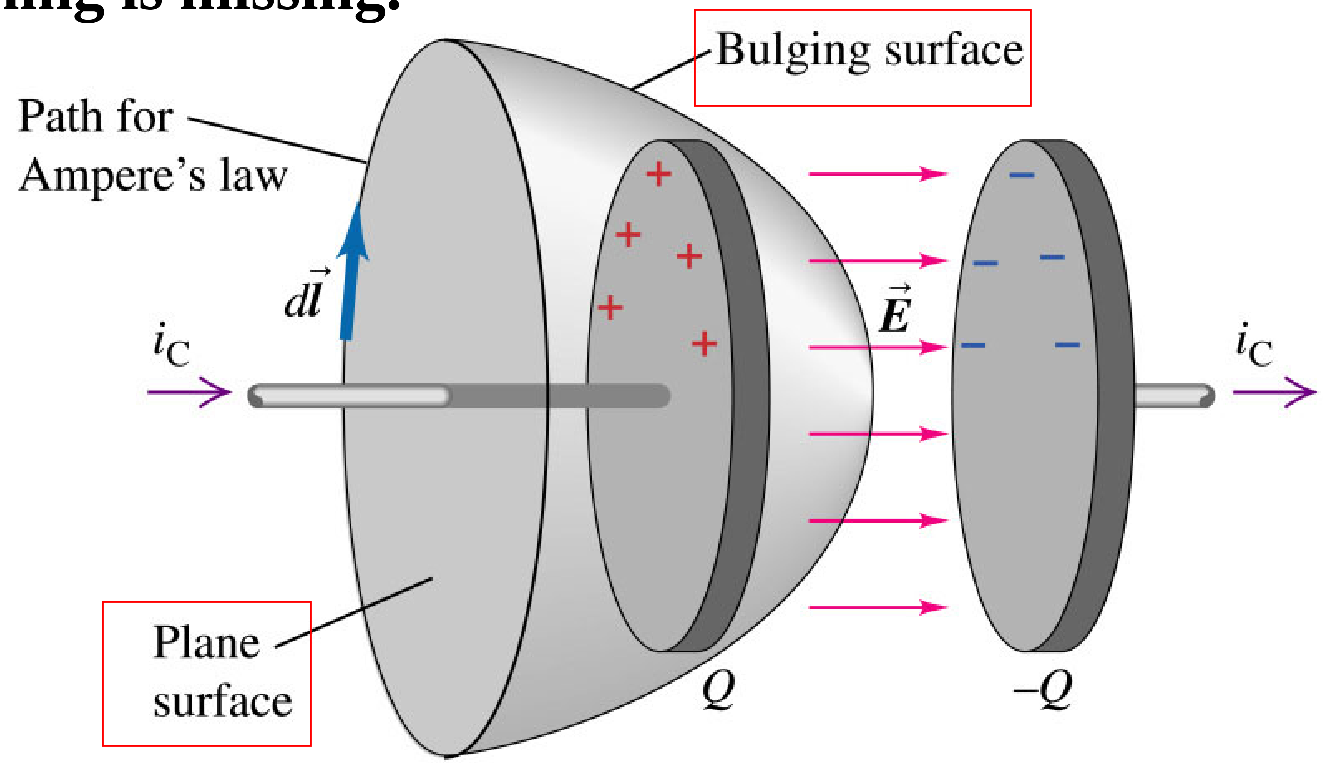
Faraday's Law works for any closed Loop and <u>ANY</u> attached surface area



This is proved in Vector Calculus with Stoke's Theorem

Generalized Ampere's Law and displacement current

Ampere's original law, $\int \vec{B} \cdot dl = \mu_0 I_{enclosed}$ **, is incomplete. Consider the parallel plate capacitor and suppose a current i_c is flowing charging up the plate. If Ampere's law is applied for the given path in either the plane surface or the bulging surface we we should get the same results, but the bulging surface has i_c=0, so something is missing.**



Generalized Ampere's Law and displacement current

Maxwell solved dilemma by adding an additional term called displacement current, $\boldsymbol{i_D} = \varepsilon\, d\Phi_E/dt$, in analogy to Faraday's Law.

$$\int \vec{B} \cdot dl = \mu_0 (i_c + i_D) = \mu_0 \left(i_c + \varepsilon_0 \frac{d\Phi_E}{dt} \right)$$

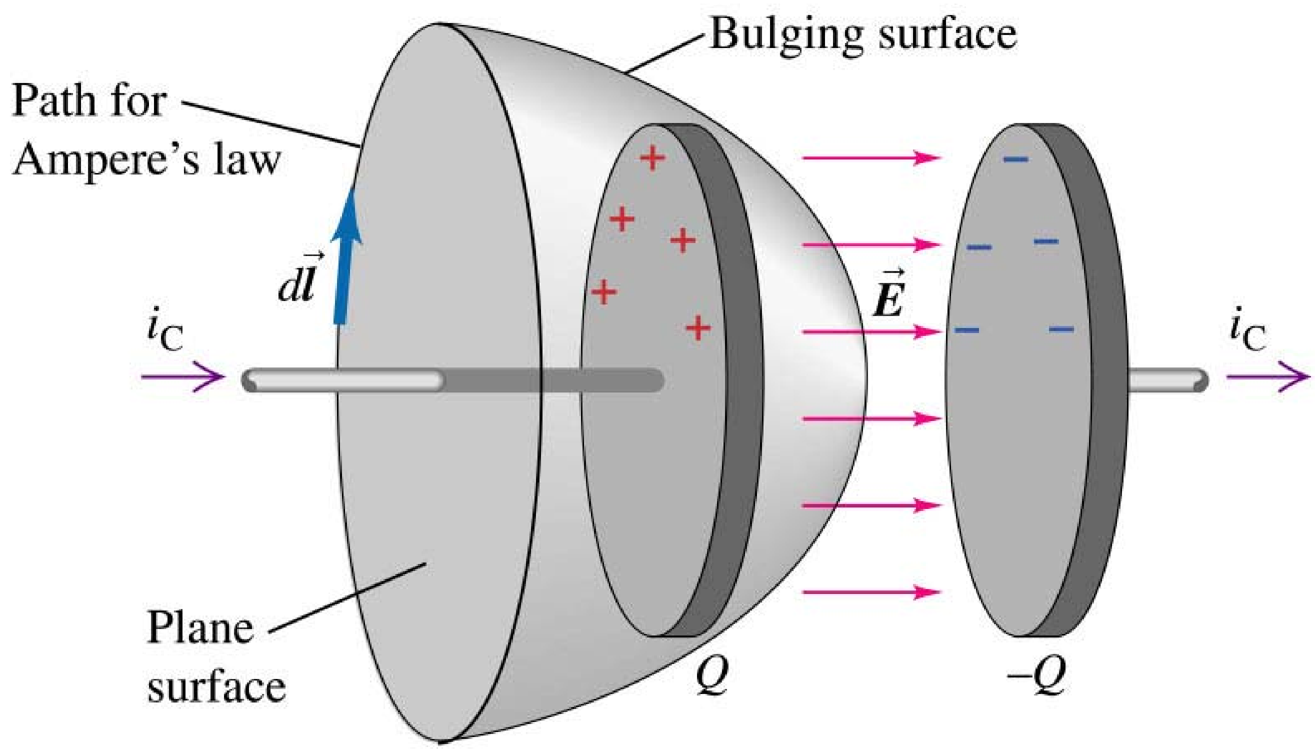
Current is once more continuous: i_D between the plates = i_C in the wire.

$$q = CV$$

$$= \frac{\varepsilon A}{d}(Ed)$$

$$= \varepsilon EA = \varepsilon \Phi_E$$

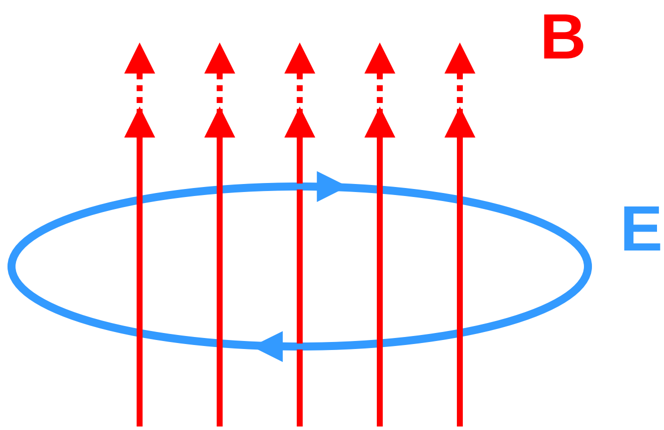
$$\frac{dq}{dt} = i_C = \varepsilon \frac{d\Phi_E}{dt}$$



Summary of Faraday's Law

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$$

If we form any closed loop, the line integral of the electric field equals the time rate change of magnetic flux through the surface enclosed by the loop.



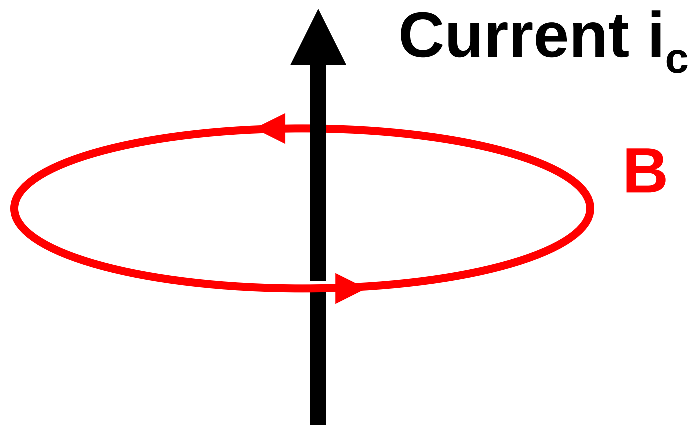
If there is a changing magnetic field, then there will be electric fields induced in closed paths. The electric fields direction will tend to reduce the changing B field.

Note; it does not matter if there is a wire loop or an imaginary closed path, an E field will be induced. Potential has no meaning in this non-conservative E field.

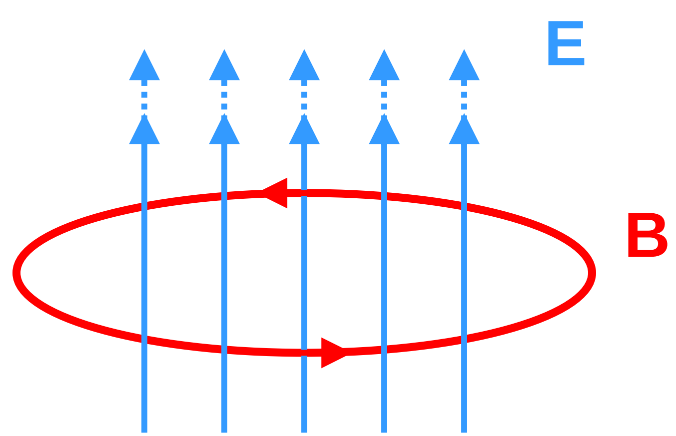
Summary of Ampere's Generalized Law

$$\oint \vec{B} \cdot dl = \mu_0 \left(i_c + \varepsilon_0 \frac{d\Phi_E}{dt} \right)$$

If we form any closed loop, the line integral of the B field is nonzero if there is (constant or changing) current through the loop.



If there is a changing electric field through the loop, then there will be magnetic fields induced about a closed loop path.



Maxwell's Equations

James Clerk Maxwell (1831-1879)

- generalized Ampere's Law
- made equations symmetric:
  - a changing magnetic field produces an electric field
  - a changing electric field produces a magnetic field
- Showed that Maxwell's equations predicted electromagnetic waves and $c = 1/\sqrt{\varepsilon_0 \mu_0}$
- Unified electricity and magnetism and light.

All of electricity and magnetism can be summarized by Maxwell's Equations.

Maxwell's Equations (integral form – also diff form)

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Gauss' Law for Magnetism	$\int \vec{B} \cdot d\vec{A} = 0$	Magnetic fields
Faraday's Law	$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$	Electrical effects from changing B field
Generalized Ampere's Law	$\oint \vec{B} \cdot dl = \mu_0 \left(i_c + \varepsilon_0 \frac{d\Phi_E}{dt} \right)$	Magnetic effects from current

… and then out of the darkness, there was light

Spring Break fun?

- Enjoy next week – though get HW #9 done
- Review on Monday; go over practice exam
  [Midterm 2 is Chap 25 – 29]
- Quiz now! After quick summary