Lecture 30 iq26

1. Current loop in a motor and in a generator
    - Loop-magnet equivalence
    - B exerts a torque on a current loop – physics principle leads to a motor
    - Rotating loop leads to emf – physics principle leads to a generator

2. Chapter 22: Part-II: Gauss law beyond the simple symmetric cases
    - Gauss law where S can have an arbitrary shape
    - Clicker 29-1: Flux through one surface of a cube
    - Clicker 29-3: Surface charge at a cavity
    - Clicker 29-4: Find E at P due to surface charges

3. E near any surface of a conductor
    - Relationship between E near a surface and the surface charge density
    - Surface charges on a capacitor
    - Applications:
        - Surface charges on 2 || capacitor plates,
        - Two parallel conducting plates: one with +5Q and one with -3Q.

4. Ampere's law beyond the simple symmetric cases. See HW and Extra problems in both unit 2 and unit3.

Announcement:

Learning module:

Feedback will be incorporated into the lecture.

The learning modules will count as part of the homework score: instead of homework accounting for 15%, we now have homework at 12% and leaning modules at 3%.

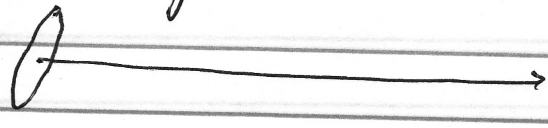
Feedback on homework: The feedback will be used as the basic content for discussion sessions. In order to encourage participation, we have made HW feedback part of the iq clicker credit:

- iq clicker now counts for 5%,
- while feedback counts for 2%.

The latter is an easy 2%, as all you need to do is tell us which problem you found most confusing on a particular assignment and why. The feedback will be due on the same evening the homework is due, but the due time will be 11:50 to give those last-minute types a chance to enter feedback after completing the homework.

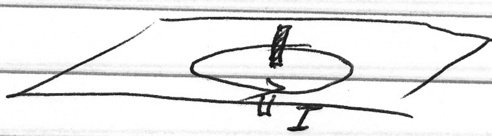
Current loop in motors and generators —

We recall current loop generates magnetic field.

• 

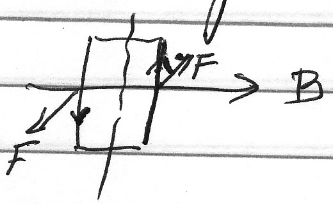
$B_z \propto \frac{1}{z^3}$

$B_z = \left(\frac{\mu_0}{4\pi}\right)\frac{2I\pi R^2}{z^3}$, $\vec{\mu}_{loop} = IA\hat{n}_{loop}$



current loop is equivalent to a magnet

loop - magnet, duality ✓

• 

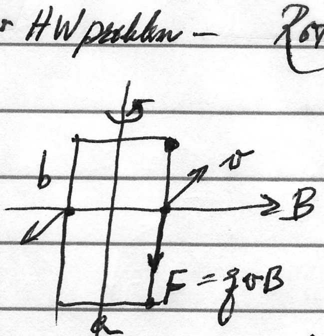
B exerts a torque on the current loop

$\vec{\tau} = \vec{\mu} \times \vec{B}$

Principle behind a motor Fig 21.53

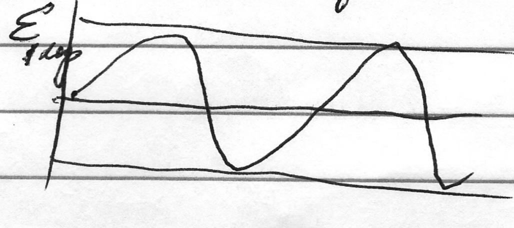
With split ring arrangement the loop can rotate continuously — Principle behind a motor.

• Your HW problem — Rotating loop generates emf in a loop



Max emf is when B aligns with the plane of the loop (rectangle: a×b)

$\mathcal{E}_{max} = 2\frac{qvBb}{q} = 2vBb = 2\frac{a}{2}\omega Bb = \omega abB$



$\mathcal{E} = (\omega abB)\sin\omega t$

Chapter 22 - part II

1. Beyond simple and symmetric applications of Gauss Law + Ampere's Law

Gauss Law: Point charge $E = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$, $4\pi r^2 E = \frac{Q}{\epsilon_0}$

$\Rightarrow 4\pi r^2 E = Q/\epsilon_0$

$\Rightarrow 2\pi r h E = Q/\epsilon_0$

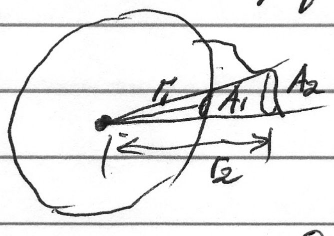
$\Rightarrow 2AE = \frac{Q}{\epsilon_0}$

Simple symmetric: part I

General form $\oint_S \vec{E}\cdot d\vec{A} = \frac{Q_S}{\epsilon_0}$

S can be arbitrary, Q_S any charge distribution enclosed by S.

Begin with 1 point charge q with arbitrary surface S which encloses q.



$$\left\{\begin{array}{l} E_1 A_1 = \frac{1}{4\pi\epsilon_0}\cdot \underbrace{\frac{q}{r_1^2}\,\hat{r}_1\cdot A_1}_{\Delta\Omega} \\ E_2 A_2 = \frac{1}{4\pi\epsilon_0} q\,\Delta\Omega \end{array}\right.$$

Same

over enclosing surface $LHS = \frac{1}{4\pi\epsilon_0} q \underbrace{\oint \Delta\Omega}_{4\pi} = \frac{q}{\epsilon_0}$

Let $Q_s = \sum_k q^{(k)}$

Superposition: $\oint_S E^{(k)}\cdot dA = \frac{\sum^k q_k}{\epsilon_0}$ ✓ end of proof

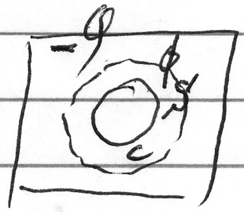
2. Clicker 29-1 Find the flux thru Shaded Area

Total flux: $\frac{q}{\epsilon_0}$

Thru 1 cube $\times \frac{1}{8}$ $\therefore$ Thru 6n square phase: $\frac{q}{\epsilon_0}\times\frac{1}{24}$

Thru 1 face $\times \frac{1}{3}$

Clicker 29-3



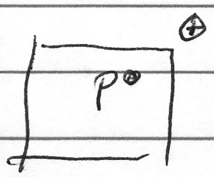
$\oplus q$ Find: Surface charge at cavity

Hint: $\Phi_s = 0 \Rightarrow$ no net charge inside

Clicker 29-4 Find: $\vec{E}$ at P due to all charges $= 0$

~~Due to surface charges only~~

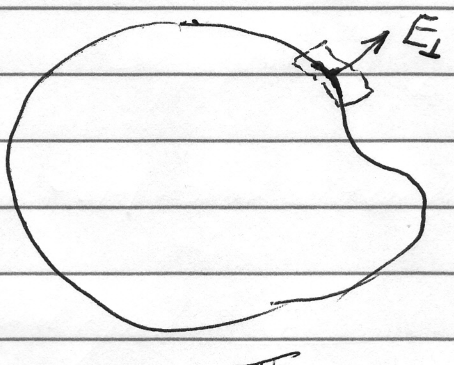
$$E_p = E_p^{surface\ chg} + E_p^{\oplus} = 0$$



$$\therefore \vec{E}_p^{\,surface} = -E_p^{\oplus}$$

$$\therefore \vec{E}_p = -E_p^{\oplus} = -\swarrow = \nearrow$$

3. Field near the surface of a conductor



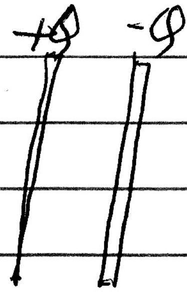
Gauss Law

$$E_\perp \Delta A = \frac{\Delta q_{surface}}{\epsilon_0}$$

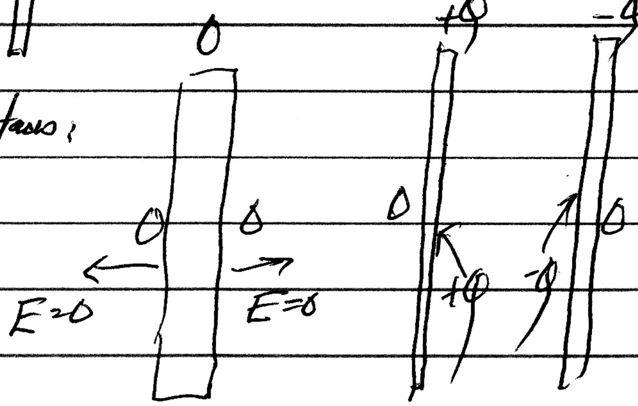
$$E_\perp = \frac{\sigma_{surface}}{\epsilon_0}$$

Theorem: $E_\perp \Leftrightarrow \dfrac{\Delta Q_{surface}/\Delta A}{\epsilon_0}$

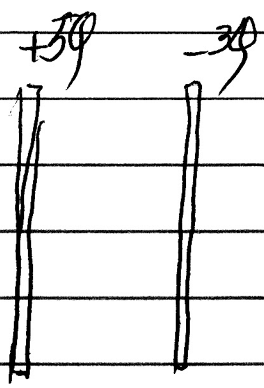
Applications: Determine surface charges by inspection

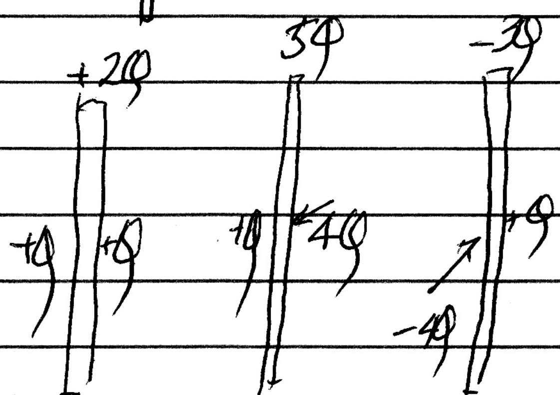


Outer surfaces:



$\therefore E_{gap} = \dfrac{Q/A}{\varepsilon_0}$





$\therefore E_{gap} = \dfrac{4Q/A}{\varepsilon_0}$

Ampere's Law: $\oint_{\mathcal{L}} \vec{B}\cdot d\vec{s} = \mu_0 I_{\mathcal{L}}$; $I_{\mathcal{L}}\big|^{in} + I_{\mathcal{L}}\big|^{out} = I_{\mathcal{L}}^{in}$ Read text