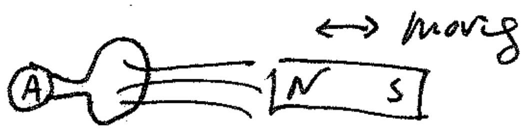
Chapter 31 Faraday's law

31.1 Faraday's law of Induction

- emf can be induced by a changing magnetic field



A current can be set up even there is no batteries present

→ The emf induced in a circuit is directly proportional to the time rate of change of the magnetic flux through the circuit

Faraday's law of induction

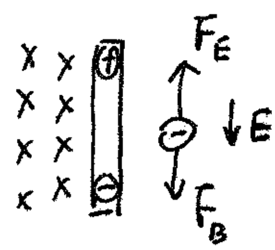
$$\mathcal{E} = -\frac{d\Phi_B}{dt} \qquad \Phi_B = \int B \cdot dA$$

$$= -N\frac{d\Phi_B}{dt} \quad \text{for a coil of } N \text{ loops.}$$

$$= -N\frac{d}{dt}(BA\cos\theta)$$

Applications: electric guitar

31.2 Motional emf.



$F_B = q v \times B$ · q = electrons in the conductor

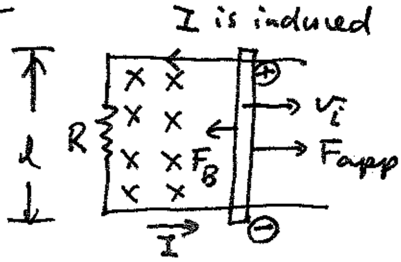
$qE = qvB$ or $E = vB$

But $\Delta V = E\ell$

$= B\ell v$

$\therefore \Delta V = B\ell v$

31.9
Figure 31.10



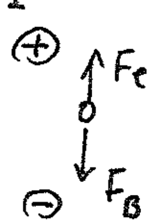


Fig. 31.7

$\Delta V = Bl v$. The potential is maintained as long as the conductor moves at constant velocity

for the circuit, the area is lx, $x \equiv$ position of the conductor

$$\Phi_B = Blx$$

Using Faraday's law

$$\mathcal{E} = -\frac{d\Phi_B}{dt} = -\frac{d}{dt}(Blx) = -Bl\frac{dx}{dt} = -Blv$$

$$I = \frac{|\mathcal{E}|}{R} = \frac{Blv}{R}$$

Power delivered by the applied force

$$\mathcal{P} = F_{app} v = (IlB)v = \frac{Blv}{R} Blv = \frac{B^2 l^2 v^2}{R} = \frac{\mathcal{E}^2}{R}$$

31.3 Lenz's law

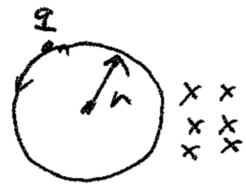
— The induced current in a loop is in the direction that creates a magnetic field that opposes the change in magnetic flux through the area enclosed by the loop.

Check Fig 31.14 page 978

31.4 Induced emf and electric field.

— Relate the induced current in a conducting loop to an electric field is created in the conductor as a result of changing magnetic flux

emf $\mathcal{E} = -\frac{d\Phi_B}{dt}$ Faraday's law



$q\mathcal{E} = qE(2\pi r) \equiv$ work done on q

Emf

$$\therefore E = \frac{\mathcal{E}}{2\pi r} = -\frac{1}{2\pi r}\frac{d\Phi_B}{dt} = -\frac{r}{2}\frac{dB}{dt} \qquad \Phi_B = BA = \pi r^2 B$$

But $\mathcal{E} = \oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$ Faraday's law of induction

31.7 Maxwell's Equation

- James Clerk Maxwell
- fundamental to E+M (just like Newton's law to Mechanics)
- $C = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 3\times10^8\ m/sec$ → Speed of E+M wave

Maxwell's Equation

$$\oint_S \vec{E}\cdot d\vec{A} = \frac{q}{\epsilon_0}$$ — Gauss's law in Electricity. Single charge is possible

$$\oint B\cdot dA = 0$$ — Gauss's law in Magnetism. Magnetic monopole is not existing

$$\oint \vec{E}\cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$ — Faraday's law of induction. An Emf is induced when there is a change in magnetic flux

$$\oint \vec{B}\cdot d\vec{s} = \mu_0 I + \epsilon_0\mu_0 \frac{d\Phi_E}{dt}$$

- Ampere-Maxwell's law
- Creation of magnetic field by electric field and electric current

If a charge is placed in space in an existing of Electric field and magnetic field.

→ the force acts on charge q is

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

— Lorentz force law