Force

Gravtional force Gravtional field =

Electrical force Electrical field

Timeline

Description automatically generatedWaves

🡪 <Opposite sign positve diection> <Same sign negative direction>

Lossy media

AC/DC circuit

Real battery terminal voltage Kirchhoff current node law and voltage loop rule

Power (W)

AC voltage

Resistor in AC: no phase difference

Capacitor in AC: Current leads voltage by 90º

Inductor in AC: Current lags voltage by 90º

A picture containing text, receipt

Description automatically generatedText

Description automatically generated

RLC circuit maximum frequency

Attenuating wave:

Timeline

Description automatically generated

Transmission lines

Lines affects

* When is very small ignore effects
* When , need to account for phase delay and possibly reflection
* When , definitely need to account for phase delay and possibly reflection

Graphical user interface, text, application

Description automatically generated

Air line:

Dispersion 🡪Distorts signals because different frequency components 🡪 Proportional to the length of the transmission line

Graphical user interface, application

Description automatically generated

Text, letter

Description automatically generated

Graphical user interface, text, application

Description automatically generated

Lossless transmission line

Text

Description automatically generatedR’ and G’ are negligible 🡪

Graphical user interface, text, application

Description automatically generated

Table

Description automatically generatedTable

Description automatically generatedVector analysis

* Cylindrical <r, ϕ, z>
* Spherical <R, θ, ϕ>
* Gradient ()
* Chart, diagram, radar chart

  Description automatically generatedDivergence ()
* Curl ()
  + = (
* Stroke’s theorem
* Divergence theorem

Gradient of cylindrical coordinate 🡪

Text, letter

Description automatically generatedGradient of Spherical coordinate 🡪

Coulomb’s Law (Find electric field given charge)

Infinite Plane (Disk) of charge Infinite line of charge

Gauss’s Law (Find charge given a field)

Diagram, text

Description automatically generatedElectric Potential

Dielectrics

* An electric dipole consists of 2-point charges of equal magnitude but opposite polarity
  + Diagram

    Description automatically generatedApplications: Dielectrics, molecular bonds, antennas

only when R>>d

Types of dipoles in matter

* Permanent
  + Molecule having atoms with different electronegativity
  + Polar molecule 🡪 water
* Instantaneous
  + Electrons happen to concentrate in one place
* Induced
  + A permanent dipole or applied electric field near another atom induces a dipole

In a dielectric material

Conductors & Resistors

* Conductors are materials in which some of the electrons are free electrons
  + Electrons can move relatively freely through the material
  + Copper, aluminum, and silver
  + Charge Carrier: A particle carrying charge that is free to move

Drift velocity, u: Steady state average velocity of the electrons

Mobility µ: Accounts for the effective mass of charged particle and the average distance before stopped by colliding

Semiconductor / dielectric

Conductor For perfect dialectic:

For perfect conductor

Electric Boundary Conditions

Table

Description automatically generated🡨 General Boundary Conditions

DD: &

DC:

Diagram

Description automatically generated with low confidenceChart, line chart

Description automatically generated

Text

Description automatically generated with low confidenceDielectric – dielectric Dielectric – conductor Conductor – Conductor

Capacitor

Magnetic Forces and torques

Biot-Savart Law

Text, letter

Description automatically generatedMagnetic field of a loop

At z = 0

At points far away

Diagram

Description automatically generated with medium confidenceR is the distance from center to point P, a is length of wire segment

For an infinity long wire

Ampere’s law (Gauss’s Law for magnetism) (net magnetic flux through a closed Gaussian surface is 0)

H field for long wire:

H field for toroidal coil:

H field inside long solenoid:

H field of current sheet:

Magnetic vector potential & Magnetic material

Spin Magnetic Moments: Angular momentum:

Magnetization:

M is sum of magnetic dipole moments in medium

Table

Description automatically generated

Inductor

Self-inductance in a solenoid:

Energy stored in solenoid: Energy density Total energy in any volume

Self-inductance of toroid:

Faraday’s Law

* A time varying magnetic field creates transformer emf V
* A moving loop with time-varying surface area in static field B create motional emf
* A moving loop in time-varying field B is transformer emf + motional emf

Lenz’s Law

* The current in the loop is always in a direction that opposes the change of magnetic flux that produced I

A picture containing text, clock

Description automatically generatedMoving Conductor in a static magnetic field

Transformers

Diagram

Description automatically generated

DC Generators: Same components as AC generator, main difference is contacts to the rotating loop are made using a split ring called commutator.

Motor: Electrical to mechanical energy Generators works opposite

Motors are devices into which energy is transferred by electrical transmission while energy is transferred out by work

EM Motor: A current is supplied to the coil by a battery and the torque acting on the current carrying coil causes it to rotate

* Induced back emf, acts to reduce the current in the coil
* The back emf increases in magnitude as the rotational speed of coil increases

The displacement current

Diagram

Description automatically generated

Continuity of current flow through the circuit

* The displacement current behaves like a real current
* The displacement current accounts for polarization in the medium
* The perfect wire has infinite conductivity
  + If it has finite conductivity, then D in the wire would be non-zero and would consist of both conduction and displacement currents
* A magnetic field can be produced either by currents or by changing electric fields

* An electric field can be produced either by charges or changing magnetic fields