APECpedia

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Contents

Preface

Throughout this text vectors are displayed in bold face.

Part I

Physical Models

Chapter 1

Quantum Mechanics

1.1 Dirac equation

$$(i\gamma^\mu \partial_\mu - m)\,\psi = 0$$

where
γ^μ are the gamma matrices.

Chapter 2

Classical Mechanics

2.1 Newton's Law of Gravitation

$$\mathbf{F} = -G\frac{m'm}{r^3}\mathbf{r}$$

Chapter 3

Electromagnetism

SI units are used throughout this chapter.

3.1 Force Fields in Terms of Potential Fields

$$\mathbf{E} = -\nabla\phi - \frac{\partial \mathbf{A}}{\partial t} \tag{3.1}$$

$$\mathbf{B} = \nabla \times \mathbf{A} \tag{3.2}$$

3.2 Maxwell's Equations

Coulomb's law:

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon} \tag{3.3}$$

Gauss law:

$$\nabla \cdot \mathbf{B} = 0 \tag{3.4}$$

Faraday's Law of Induction:

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \tag{3.5}$$

Ampere's Law with Maxwell's correction:

$$\nabla \times \mathbf{B} = \mu \mathbf{J} + \frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t} \tag{3.6}$$

Constitutive Relations (isotropic medium):

$$\mathbf{D} = \epsilon \mathbf{E}$$

$$\mathbf{B} = \mu \mathbf{H}$$

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

Other:

$$c = \frac{1}{\sqrt{\mu\epsilon}}$$

Where:
$\mathbf{E}$ = Electric field intensity/strength
$\mathbf{H}$ = Magnetic field intensity/strength
$\mathbf{B}$ = Magnetic induction / Magnetic flux density
$\mathbf{D}$ = Electric displacement / Electric flux density
c = velocity of light in the medium
σ = Conductivity

Note that if the medium is not isotropic then ϵ and μ become tensors. For instance, in the presence of a gravitational field the refractive index of the vacuum changes due to its effect on virtual electron-positron pairs.

When using the Maxwell's equations on problems where we have paths, surfaces and/or volumes changing with time, in such cases the integral form of the equations must be used.

3.3 Lorentz Force

$$\mathbf{F} = q\left(\mathbf{E} + \mathbf{v} \times \mathbf{B}\right)$$

3.4 Scalar Waves

Scalar waves result when the electric and magnetic field components are zero, but not so the electric and/or magnetic potentials.

In scalar waves the Lorentz gauge needs not to be zero, but becomes instead an scalar field S [1]:

$$S = -\frac{1}{c^2}\frac{\partial \phi}{\partial t} - \nabla \cdot \mathbf{A} \tag{3.7}$$

By replacing equations 3.1, 3.2 and 3.7 in Maxwell's equations 3.3-3.6 we get the two potential wave equations:

$$\left(\frac{1}{c^2}\frac{\partial^2 \phi}{\partial t^2} - \nabla^2 \phi\right) + \frac{\partial S}{\partial t} = \frac{\rho}{\epsilon}$$

$$\left(\frac{1}{c^2}\frac{\partial^2 \mathbf{A}}{\partial t^2} - \nabla^2 \mathbf{A}\right) - \nabla S = \mu \mathbf{J}$$

If the electric field is zero, then from equation 3.1 we have [2]:

$$\nabla\phi + \frac{\partial \mathbf{A}}{\partial t} = 0 \tag{3.8}$$

Equation 3.8 can always be satisfied if a scalar field χ exists such that

$$\mathbf{A} = \nabla\chi \tag{3.9}$$

and

$$\phi = -\frac{\partial \chi}{\partial t} \tag{3.10}$$

If in addition the scalar field S is zero, then by replacing equations 3.9 and 3.10 in 3.7 we get the wave equation for the new scalar field χ:

$$\frac{1}{c^2}\frac{\partial^2 \chi}{\partial t^2} - \nabla^2\chi = 0 \tag{3.11}$$

Chapter 4

Einstein's Relativity Theory

4.1 Special Relativity

Composition law for velocities [3]:

$$v_{AC} = \frac{v_{AB} + v_{BC}}{1 + v_{AB}v_{BC}}$$

4.2 General Relativity

Einstein's Field Equations:

$$G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}$$

$R_{\mu\nu}$is the Ricci Tensor
R is the Curvature Scalar
$T_{\mu\nu}$is the Energy-Momentum Tensor

Bibliography

[1] van Vlaenderen, Koen J. *A generalisation of classical electrodynamics for the prediction of scalar field effects.* 2003 (physics/0305098v1).

[2] Dea, Jack. *Fundamental fields and phase information.* Planetary Association for Clean Energy Newsletter, Vol. 4, Number 3.

[3] d'Inverno. *Introducing Einstein's Relativity.* Oxford.