# Modern Physics

A Collection of Notes and Problems

**Tarang Srivastava**

Dr. Mesut Çakir
Modern Physics
South Brunswick High School
20 April 2019

# Contents

# Chapter 1

# Lies From Classical Physics

## 1.1 Mechanics

*kinetic energy* is defined by

$$K = \frac{1}{2}mv^2$$

and *linear momentum* $\vec{p}$ defined by

$$\vec{p} = m\vec{v}$$

In terms of the linear momentum, the kinetic energy can be written

$$K = \frac{p^2}{2m}$$

Corresponding to external force there is often a potential energy $U$ such that (for one dimensional motion)

$$F = -\frac{dU}{dx}$$

The total energy

$$E = K + U$$

When a particle moving with linear momentum $\vec{p}$ is at a displacement $\vec{r}$ from the origin $O$, its *angular momentum* $\vec{L}$ about the point $O$ is defined by

$$\vec{L} = \vec{r} \times \vec{p}$$

## 1.2 Electricity and Magnetism

The electrostatic force exerted by a charged particle $q_1$ on another charge $q_2$ has magnitude

$$F = \frac{1}{4\pi\epsilon}\frac{|q_1||q_2|}{r^2}$$

Using the previous relationship between potential energy and external force

$$U = \frac{1}{4\pi\epsilon}\frac{q_1 q_2}{r}$$

Electrostatic potential difference $\Delta V$ is given by

$$\Delta U = q\Delta V$$

For reference

$$1eV = 1.602 \times 10^{-19} J$$

A magnetic field $\vec{B}$ can be produced by current $i$. The magnetic field through a loop of radius $r$.

$$B = \frac{\mu_0 i}{2r}$$

*magnetic moment* $\vec{\mu}$ of a current loop:

$$|\vec{\mu}| = iA$$

where $A$ is the geometrical area enclosed by the loop.
When a current loop is placed in a uniform external magnetic field $\vec{B_{ext}}$ there is a torque $\vec{\tau}$

$$\vec{\tau} = \vec{\mu} \times \vec{B_{ext}}$$

potential energy is given by

$$U = -\vec{\mu} \cdot \vec{B_{ext}}$$

Electromagnetic waves travel in free space with speed $c$(speed of light), which is related to the electromagnetic constants $\epsilon_0$ and $\mu_0$

$$c = (\epsilon_0 \mu_0)^{-1/2}$$

EM waves with frequency $f$ and wavelength $\lambda$ are related

$$c = \lambda f$$

# 1.3 Kinetic Theory of Matter

ideal gas equation

$$PV = NrT$$

The average kinetic energy of a molecule depends on its temperature

$$K_{av} = \frac{3}{2}kT$$

# 1.4 Failures of Classical Concepts of Space and Time

## 1.4.1 Failure in Concept of Time

Newton's laws are based on the assumption that time is the same, irrespective of the observer. This is shown to be incorrect.

## 1.4.2 Failure in Concept of Space

Galileo and Newton's theories are based on the assumption that space is the same, but this is not the case.

## 1.4.3 Failure in Concept of Velocity

If space and time are not the same no matter what the same can be said for velocity, since velocity is dependent on space and time.
There is also a speed limit on the universe we call the *speed of light c*