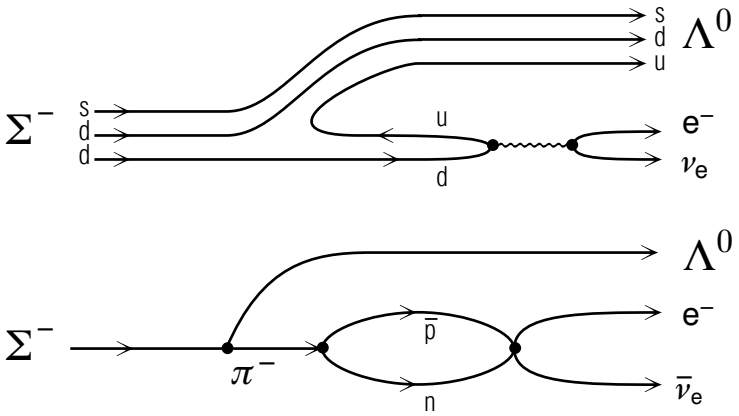
PHYSNET

MISN-0-275

CONSERVED QUANTITIES: AN OVERVIEW



Project PHYSNET Physics Bldg. Michigan State University East Lansing, MI

CONSERVED QUANTITIES: AN OVERVIEW

by

J. Christman, U. Coast Guard Academy

1. Introduction
a. Overview 1
b. Definition of "Conserved Quantity." 1
c. Quantities Conserved Depend on Interaction 1
d. Correlation With Interaction Strength 1

2. Assigned Reading 2

3. Universally Conserved Quantities
a. List of Properties 2
b. Intrinsic vs. Dynamic Properties 2
c. CPT 3

4. Properties Conserved by Each Interaction
a. Weak Force: Only Universal Quantities 3
b. EM and Strong Forces: Additional Constraints 3
c. Time Reversal Indicates Two Weak Forces 3

Acknowledgments 3

Title: **Conserved Quantities: An Overview**

Author: J.R. Christman, Dept. of Physical Science, U. S. Coast Guard Acad., New London, CT

Version: 2/1/2000 Evaluation: Stage B1

Length: 2 hr; 8 pages

Input Skills:

1. Vocabulary: conservation law (MISN-0-15).
2. State the family and family group to which a given strong-stable particle belongs (MISN-0-274).

Output Skills (Knowledge):

K1. Explain what is meant when an elementary-particle quantity is said to be "conserved" and when it is said to be "universally conserved."

K2. List the names of all the quantities which may be conserved in elementary particle interactions.

K3. For each type of elementary particle interaction, list the conserved quantities.

External Resources (Required):

1. K. W. Ford, *Classical and Modern Physics*, Vol. 1, John Wiley and Sons (1972).

Post-Options:

1. "Universally Conserved Quantities in Elementary Particle Interactions" (MISN-0-276).
2. "Additional Properties Conserved in Electromagnetic and Strong Interactons" (MISN-0-277).

THIS IS A DEVELOPMENTAL-STAGE PUBLICATION
OF PROJECT PHYSNET

The goal of our project is to assist a network of educators and scientists in transferring physics from one person to another. We support manuscript processing and distribution, along with communication and information systems. We also work with employers to identify basic scientific skills as well as physics topics that are needed in science and technology. A number of our publications are aimed at assisting users in acquiring such skills.

Our publications are designed: (i) to be updated quickly in response to field tests and new scientific developments; (ii) to be used in both classroom and professional settings; (iii) to show the prerequisite dependencies existing among the various chunks of physics knowledge and skill, as a guide both to mental organization and to use of the materials; and (iv) to be adapted quickly to specific user needs ranging from single-skill instruction to complete custom textbooks.

New authors, reviewers and field testers are welcome.

PROJECT STAFF

Andrew Schnepp	Webmaster
Eugene Kales	Graphics
Peter Signell	Project Director

ADVISORY COMMITTEE

D. Alan Bromley	Yale University
E. Leonard Jossem	The Ohio State University
A. A. Strassenburg	S. U. N. Y., Stony Brook

Views expressed in a module are those of the module author(s) and are not necessarily those of other project participants.

© 2001, Peter Signell for Project PHYSNET, Physics-Astronomy Bldg., Mich. State Univ., E. Lansing, MI 48824; (517) 355-3784. For our liberal use policies see:

`http://www.physnet.org/home/modules/license.html`.

CONSERVED QUANTITIES: AN OVERVIEW

by

J. Christman, U. Coast Guard Academy

1. Introduction

1a. Overview. Certain particle properties are conserved in interactions and decays. The purpose of this unit is to enumerate such properties and to discuss conservation laws in a general way. Details of the properties are discussed elsewhere.[1]

1b. Definition of "Conserved Quantity." . Here is the meaning of "conserved property" in a particle interaction or decay:

> A number representing the property can be assigned to each particle entering the interaction and to each particle produced by the interaction. There exists a scheme for calculating the total amount of the property both for particles entering and for particles leaving the interaction. If the entering total and leaving total are the same, the property is said to be conserved.

1c. Quantities Conserved Depend on Interaction. The list of properties which are conserved is characteristic of the type of interaction. Those properties which are conserved in all 4 types of interaction are called "universally conserved quantities." In addition, there is a property which is conserved in strong interactions but not in the others, and there are properties which are conserved in electromagnetic interactions but not in weak ones.

1d. Correlation With Interaction Strength. It is interesting, but perhaps coincidental, that if a property is conserved by one type of interaction it is conserved by all stronger interactions. That is, the list of conserved properties for the electromagnetic interaction contains all those on the list for the weak interaction plus four others and the list for the strong interaction includes all those for the electromagnetic interaction plus one other. Little experimental information exists for the gravitational interaction.

[1] "Universally Conserved Quantities in Elementary Particle Interactions" (MISN-0-276). Also see Reference 3.

2. Assigned Reading

Sections 4.1 through 4.7 in K.W. Ford's *Classical and Modern Physics*, Vol. 1, John Wiley and Sons, NYC (1972), on reserve for you in the PA Library: Ask for "the readings for Unit 275."

3. Universally Conserved Quantities

3a. List of Properties. These quantities are universally conserved in elementary particle interactions:[2]

a. energy

b. linear momentum

c. angular momentum

d. electric charge

e. baryon number

f. electron-muon-tauon number.

g. lepton number

In special relativity, energy becomes the fourth component of the (now four-dimensional) momentum vector. Conservation of this "four-momentum" implies conservation of both energy and momentum.

3b. Intrinsic vs. Dynamic Properties. The last four properties in Sect. 3a, items d-g, are intrinsic properties of the particle. The first three, items a-c, depend on the dynamical situation. For example, electrons may have different momenta, depending on the extent to which they have been accelerated, but all electrons have the same charge, baryon number, electron number, muon number, tauon number, and lepton number.

[2] Older references may have lists of conserved quantities that are obsolete and hence differ from the up-to-date list given here.

3c. CPT. There is another quantity, called CPT, which is believed to be universally conserved. This quantity is the product of the quantities for charge conjugation invariance (C), parity invariance (P), and time reversal invariance (T). The meaning of C, P, and T are discussed elsewhere.[3]

4. Properties Conserved by Each Interaction

4a. Weak Force: Only Universal Quantities. All of the universal quantities listed in Sect. 3a are conserved by the weak interaction. With the exceptions noted in Sections 3c and 4c, no other known quantities are conserved by the weak interaction.

4b. EM and Strong Forces: Additional Constraints. In addition to the seven universal properties, these properties are also conserved by the electromagnetic interaction:

h. parity

i. strangeness

j. charge conjugation

k. time reversal

In addition to the above listed properties, the strong interaction also conserves a quantity called "isospin."

4c. Time Reversal Indicates Two Weak Forces. Effects which stem from the violation of time reversal invariance by the weak interaction are roughly one-thousandth as strong as the more usual effects of the weak interaction. This has led some physicists to believe that the force which has been traditionally called the weak interaction is, in reality, two forces, the stronger of which is time reversal invariant and the weaker of which is not. This super weak force, if it exists, is a fifth force of nature. Here we do not make a distinction between these two weak forces.

Acknowledgments

Preparation of this module was supported in part by the United States Coast Guard Academy for a Directed Studies Program. Preparation of this module was supported in part by the National Science Foundation, Division of Science Education Development and Research, through Grant #SED 74-20088 to Michigan State University.

[3] "Additional Properties Conserved in Electromagnetic and Strong Interactions" (MISN-0-277).