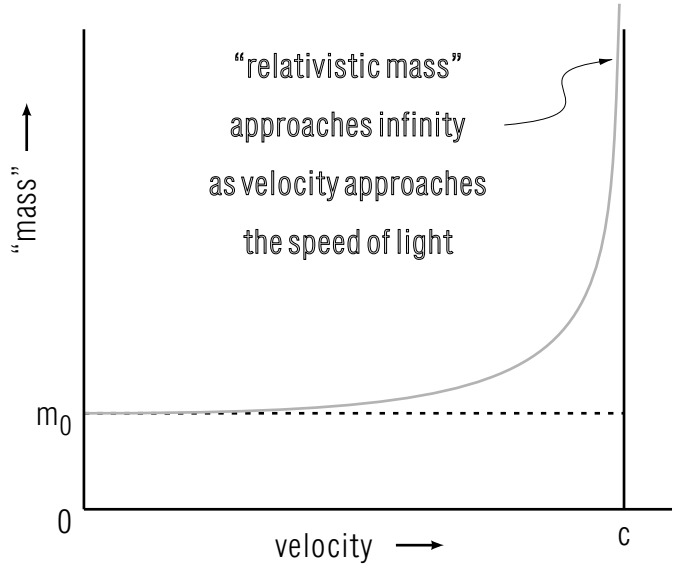
PHYSNET

MISN-0-74

RELATIVISTIC ENERGY AND MOMENTUM: DERIVATION



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

RELATIVISTIC ENERGY AND MOMENTUM: DERIVATION

by

Frank Zerilli

1. Study In WSM 1

Acknowledgments 1

Title: **Relativistic Energy and Momentum: Derivation**

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Version: 2/1/2000 Evaluation: Stage B1

Length: 1 hr; 8 pages

Input Skills:

1. Vocabulary: Lorentz transformation (MISN-0-12).
2. Use the Lorentz contraction and time dilation formulas to transform lengths and time intervals from one inertial reference frame to another (MISN-0-13).
3. Expand a given function about a point using a Taylor series (MISN-0-4).

Output Skills (Knowledge):

K1. Describe a collision experiment that shows how to define a relativistic momentum which is conserved in the absence of external forces and which reduces to the Newtonian momentum for small velocities.

K2. Define a relativistic kinetic energy in terms of the work done in bringing a particle from rest to a velocity v under the action of relativistic force F.

K3. Derive a formula for the relativistic kinetic energy which reduces to the non-relativistic expression for kinetic energy, $mv^2/2$, for small velocities.

External Resources (Required):

1. R.T. Weidner and R.L. Sells, *Elementary Modern Physics*, Allyn and Bacon, Boston (1980). For availability, see this module's *Local Guide*.

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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.

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1. Study In WSM

Study in WSM[1] Section 3-1 for Output Skill K1 (see this module's *ID Sheet*). By examining the collision illustrated in Fig. 3-1 in two different frames of reference and applying the Lorentz contraction and time dilation formulas we determine that the quantity $m_0 v/\sqrt{1 - v^2/c^2}$ is conserved in the collision and it reduces to the ordinary non-relativistic expression for momentum for small velocities, so we call this quantity relativistic momentum.

Study in WSM Section 3-2 for Output Skills K2 and K3. The relativistic force is defined as the rate of change of relativistic momentum and, as we do in non-relativistic mechanics, the relativistic kinetic energy is defined as the work done by the force in accelerating a mass from zero velocity to a velocity v. This is just the integral of the relativistic force over the distance traveled by the mass. The resulting expression reduces to the usual non-relativistic form for small velocities.

Acknowledgments

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.

[1] R. T. Weidner and R. L. Sells, *Elementary Modern Physics*, 3rd ed., Allyn and Bacon (1980). For availability, see this module's *Local Guide*.

LOCAL GUIDE

The readings for this unit are on reserve for you in the Physics-Astronomy Library, Room 230 in the Physics-Astronomy Building. Ask for them as "The readings for CBI Unit 74." Do **not** ask for them by book title.