BASIC PHYSICS

Notes for Traffic Crash Investigators and Reconstructionists

ABOUT THE AUTHOR

R.W. (Bob) Rivers is a graduate of Northwestern University Traffic Institute's traffic accident investigation and police management training programs. He completed training with the Canadian Institute of Science and Technology in technical mathematics and areas of physics, studied psychology at the Okanagan Regional College, completed police administration training programs through the Canadian Police College and the University of Minnesota, and patrol management with the IACP. He developed the traffic accident investigation and traffic law enforcement training programs of the Royal Canadian Mounted Police and course training standards for the Canadian Police College, University of Alberta, and the British Columbia Institute of Science and Technology in technical traffic accident investigation. During his 33 years service with the Royal Canadian Mounted Police, Inspector Rivers was employed extensively in general police work, highway patrol, accident investigation, research and planning, and training and development. Since his retirement, Inspector Rivers has authored various internationally-recognized textbooks, acted as a consultant and has assisted in traffic accident investigation training and research studies on an international basis (see web site: www.nanaimo.ark.com/rivers~/).

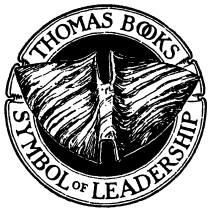
BASIC PHYSICS

Notes for Traffic Crash Investigators and Reconstructionists

An Introduction for Some
A Review for Others

By

R.W. RIVERS



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PREFACE

This manual is intended to provide a basic understanding of physics as applied to traffic crash investigation and reconstruction and to provide an understanding of the subject that will lead to advancement in this profession. It is intended to serve a need for investigators who possess a good knowledge and understanding of elementary algebra and trigonometry, and who have successfully completed at least an at-scene traffic crash investigation course and wish to further their knowledge towards competency in advanced traffic crash investigation and reconstruction.

The range of topics included are those considered to be fundamental and which best serve the purposes of illustrating the methods and procedures vital as an introduction to physics. Essentials of the subject as related to vehicle motion are stressed. The mathematics used is kept simple and in straightforward, easy-to-understand language. Comments and examples, and a very comprehensive list of terms and definitions, supported by many illustrations and diagrams, are provided to give the reader a unified view of basic physics, all areas of which can be easily located by using the detailed index. A goal for the reader in studying this material should be to learn to think analytically. Of utmost importance is not so much learning the answer to a particular problem involving physics, but rather a way of rationally working from knowns to determine the unknowns of any reconstruction project.

A study of this work will assist students and others who wish to increase their knowledge of physics in overcoming the drawbacks encountered with many otherwise excellently-prepared textbooks currently available which explain a given principle by an author who has an insight into the subject matter but which is not shared by the reader or student. In some of these instances, explanations are written in

an abstract manner which leave the student confused as to the application of the principle. With the basic knowledge that can be attained with this manual, the reader will be in a position to both better understand and apply these principles.

Except for a few cases, derivations of the various formulae are not shown. However, in the case of each individual formula, all elements are explained in such a manner as to make known and easily understood all factors that are involved. Complete derivations for many of the formulae used in this manual can be found in the *Derivations Manual for Formulas Used in Traffic Accident Investigation and Reconstruction,* by Wiley L. Howell, and *Fundamentals of Applied Physics for Traffic Accident Investigators* (Vol. 1), authored by John Daily and Nathan S. Shigemura, both of which are published by the Institute of Police Technology and Management (IPTM), University of North Florida. (See the bibliography or http://www.iptm.org for details).

As a manual that is prepared for use on an international basis, all mathematical and/or technical references are shown in both the United States/English system and Metric (SI). To assist the reader and to avoid confusion, conversion factors and constants will be found throughout the book. In some of the calculations shown, however, exact conversions from the English system to SI are not made in order to avoid unnecessary use of multiple significant figures in the latter. The corresponding values that appear in these cases should therefore be considered approximations. To further assist the reader, examples are shown separately for each system and they should be treated as independent of each other.

When conducting some tests involving ratios, such as determining a coefficient of friction using a drag sled, many investigators wish to use a spring scale or similar device calibrated only in pounds or kilograms. In these cases, it should be understood that when reading this manual where it might be thought that in SI only newtons should be used, the important thing to do is to use the same type of units. *Example,* in the case of a drag sled, if the weight is measured in pounds (kilograms), the force (pull) to slide the sled along the surface should likewise be measured in pounds (kilograms).

R.W.R.

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Initial Draft Reviews

Stephen R. Robinson, P.Eng., President, Robinson Forensic Engineering Inc., Moncton, N.B., Canada. Telephone: (506) 854-2526 Fax: (506) 852-2923. Cell: (506) 381-1804. E-mail: <RFEng@nbnet.nb.ca>.

Wade Bartlett, P.E., President, Mechanical Forensics Engineering Services, LLC, Rochester, NH. Telephone: (603) 332-3267. Fax: (603) 330-3347. E-mail: <wade@mfes.com> http://www.mfes.com.

John Ruller, Senior Traffic Accident Reconstructionist, Road Accident Investigation Service P/L, Bellbowrie, Qld., Australia. Telephone/Fax: 011-61-7-3202-7707. E-mail: <rjruller@eis.net.au>

Final Draft Review

John Duff, P.Eng., Ph.D., For-Eng Consultants Ltd., Sechelt, B.C., Canada. Telephone numbers: 1-800-461-8913 and 604-885-8963. Fax (604) 885-8967. E-mail: <for-eng@dccnet.com>.

R.W.R.

THE METRIC (SI) SYSTEM)

The metric system, **Le Systéme International d´Unités** (International System of Units, abbreviated *SI* in all languages) is used in most countries outside the United States. Because this manual is prepared for international use, all mathematical formulae and problem-solving examples are shown in both the *United States/Imperial* or *English* and *Metric (SI)* systems.

In North America, a decimal fraction is generally indicated by means of a (decimal) point on the line (not a dot in the raised or centered position). In this regard, it is important for North Americans and many others to understand that in some countries it is the dot in the raised position that is used. Also, that in some countries a comma is used. It is the North American practice of using the dot as a decimal point situated on the line that is followed in this manual.

DISCLAIMER

In the preparation of this manual, various published works and technical papers have been studied and consultations with experts in this field have taken place. The information and practices set out herein are, to best of the author's knowledge, experience, and belief, the most current and accurate in terms of providing a basic understanding of the physics used in traffic crash investigation and reconstruction. However, the author, publisher, and editors expressly disclaim all and any liability to any person, whether a purchaser of this publication or not, as a consequence of anything stated, done or omitted to be done, whether in whole or in part by such person in reliance upon any part of the contents of this publication. Every acceptable method, procedure or explanation may not be presented, and some individual cases or sets of circumstances may require additional or substitute procedures and explanations. Also, since statutes, ordinances, and organizational policies and procedures differ widely in various jurisdictions, those of the particular jurisdiction of the user should govern when there is any apparent conflict between them and the contents of this manual.

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Chapter 1

INTRODUCTION TO PHYSICS AND VEHICLE MOTION

INTRODUCTION

1.001 The following notes are intended to serve as an introduction for some and a review for others in relation to physics and its application to traffic crash investigation and reconstruction. The topics that are presented and the extent of their content are limited to that which is considered to be fundamental in terms of illustrating the methods and procedures vital as an introduction. The material presented should also pave the way for the study of more advanced works such as those found in the textbooks listed at the end of this manual.

PHYSICS DEFINED

1.002 The term *physics* is derived from a Greek word meaning nature. It explains and quantifies the physical world around us. Physics, as an exact science, deals with matter and energy in terms of motion, and is knowledge possessed as the result of study and practice, which is classified and accumulated.

MECHANICS AND DYNAMICS

1.003 The part of physics of special interest in traffic crash investigation and reconstruction is under what is called *mechanics.* We may define mechanics as (a) *that branch of physics dealing with the motions and states of material bodies,* or (b) *that area of physics that deals with motions and forces that move bodies through direct contact.* One exception to this, however, is the force of gravity which does not have to be in direct contact with a body to produce a motion.

Mechanics is usually divided into two parts: (1) *Dynamics* and (2) *Kinematics,* defined as follows:

1. *Dynamics.* The branch of physics that specifically deals with the influences of forces on motion and may be further divided into two parts: (a) *statics* and (b) *kinetics.*

   (i) *Statics.* The branch of physics dealing with conditions in which bodies are kept at rest by the actions of forces. The words *static* and *equilibrium* describe the forces acting in such a way that the net force on an object is zero. A body in equilibrium and at rest is said to be in static equilibrium, whereas a body moving with uniform velocity (constant speed) is said to be in dynamic equilibrium.

   (ii) *Kinetics.* The branch of physics dealing with the effect of forces in the production of modification of motion in bodies.

2. *Kinematics.* The branch of physics that deals with (a) *analytical and mathematical descriptions of all kinds of motion;* (b) t*he quantitative description of motion; involving only the description of motion and not concerned with the causes of motion.*[1] Kinematics is considered to be the starting point for mechanics.

NEWTON'S THREE LAWS OF MOTION

1.004 The principles contained in *Newton's Three Laws of Motion* form the basis of the whole subject of *mechanics* and should be thoroughly understood by the student and investigator. The three laws are:

Law 1: *Everything remains at rest or moves with constant velocity (in a straight line) unless acted upon by an external unbalanced (not counteracted) force.*

Or, stated another way:

> *A body at rest remains at rest, and a body in motion remains in motion with constant velocity, unless acted upon by some external force.*

This First Law is commonly called the *Law of Inertia.*

Law 2: *A free body acted upon by a constant force moves with constant acceleration in the direction of the force. The amount of acceleration experienced by a body is directly proportional to the acting force and inversely proportional to the mass of the body.*

Or, stated another way:

> *The time rate of change of the momentum of a body is proportional to the net external force acting upon the body and is in the direction of this force.*

Law 3: *To every action there is an equal and opposite reaction.*

Or, stated in other ways:

> *Whenever one body exerts force upon a second body, the second body exerts an equal and opposite force on the first.*
>
> *To every action there is an equal and contrary reaction.* (Here the term *action* is used to imply *force.*)

It should be noted that *action* combines force and time. The force exerted by one body on the other is equal and opposite to the force exerted by the other body on the first body. And, of course, when the first body is in contact with the second, the second must be in contact with the first. The *force x time* concept is important when dealing with collisions, and is known as *Impulse.*