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大学物理
COLLEGE PHYSICS

影印版

Frederick J. Bueche Eugene Hecht

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Frederick J. Bueche, Ph.D.
Eugene Hecht, Ph.D.

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内容简介

Schaum's丛书是由麦格劳－希尔(McGraw－Hill)国际出版公司出版的著名的系列教学辅助用书,涵盖了高等教育各类各门学科和课程。每本书都汇集了该门学科课程中的精髓内容,并对基本理论和基本概念作了简明精炼的归纳和总结,还提供了由美国众多经验丰富的资深教师和学者推荐、讲解透彻的精选例题和形式多样的各类习题。

本书根据Schaum's系列丛书中《大学物理》第九版原文影印出版。可供在校本科生、研究生以及社会各类科技人员参考使用。

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Schaum's Outline of Theory and Problems of
COLLEGE PHYSICS

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出版说明

随着我国高等教育改革形势的发展，高等教育的人才培养模式及教学形式和教学方法正在发生重大变化，一个拓宽专业口径，实行弹性学习制度，允许分阶段完成学业，横向沟通、纵向衔接的教育体制正在逐步构建形成。为了促进高等教育的改革，活跃高等学校的教学工作，扩大学生的眼界，我们组织出版了这套“Schaum's题解精萃”。

“Schaum's丛书”是由麦格劳－希尔(McGraw－Hill)国际出版公司出版的著名的系列教学辅助用书，目前已出版了约700多个品种，涵盖了高等教育各类各门学科和课程。本套丛书的特点是：每本书都汇集了该门学科课程中的精髓内容，并对基本理论和基本概念作了简明精炼的归纳和总结；同时，还提供了由美国众多经验丰富的资深教师和学者推荐、讲解透彻的精选例题和形式多样的各类习题约2000—4000个。本套书在美国高等学校中颇具权威性，多年来持续畅销，目前在世界范围销售超过3000万册。

我们从“Schaum's丛书”中经精心挑选，组合成“Schaum's题解精萃”，以原版影印的形式介绍到国内，意在使学生在使用本书的同时，了解、熟悉相关学科和课程的英语专业词汇，提高英语专业阅读的速度和水平，锻炼使用英语学习、解题的能力。因为，当今时代，熟练掌握英语已成为21世纪人才必备的基本素质和能力。“Schaum's题解精萃”第一批影印书内容涉及理工科各基础学科，今后我们将陆续影印出版该系列其他学科的图书。

本套书可供高等学校的理工科学生在学习各学科课程的同时，进行辅助学习和各类习题训练，有助于提高学生巩固学科基本知识和解题的综合能力，同时也可适用于各科教师在教学和辅导中参考。本套书同时还可作为在校本科生、研究生以及社会各类科技人员参加各类国际资格证书考试、国外留学考试(如GRE)等的适用参考书。

我们相信，本套书的出版，将会对我国高等院校的学生、教师们提供丰富多彩、形式多样、卓有成效的参考资料。

出版者

2000年4月

Preface

The introductory physics course, variously known as "general physics" or "college physics," is usually a two-semester in-depth survey of classical topics capped off with some selected material from modern physics. Indeed the name "college physics" has become a euphemism for introductory physics *without calculus*. *Schaum's Outline of College Physics* was designed to uniquely complement just such a course, whether given in high school or in college. The needed mathematical knowledge includes basic algebra, some trigonometry, and a tiny bit of vector analysis. It is assumed that the reader already has a modest understanding of algebra. Appendix B is a general review of trigonometry that serves nicely. Even so, the necessary ideas are developed in place, as needed. And the same is true of the rudimentary vector analysis that's required—it too is taught as the situation requires.

In some ways learning physics is unlike learning most other disciplines. Physics has a special vocabulary that constitutes a language of its own, a language immediately transcribed into a symbolic form that is analyzed and extended with mathematical logic and precision. Words like energy, momentum, current, flux, interference, capacitance, and so forth, have very specific scientific meanings. These must be learned promptly and accurately because the discipline builds layer upon layer; unless you know exactly what velocity is, you cannot know what acceleration or momentum are, and without them you cannot know what force is, and on and on. Each chapter in this book begins with a concise summary of the important ideas, definitions, relationships, laws, rules, and equations that are associated with the topic under discussion. All of this material constitutes the conceptual framework of the discourse, and its mastery is certainly challenging in and of itself, but there's more to physics than the mere recitation of its principles.

Every physicist who has ever tried to teach this marvelous subject has heard the universal student lament, "I understand everything; I just can't do the problems." Nonetheless most teachers believe that the "doing" of problems is the crucial culmination of the entire experience, it's the ultimate proof of understanding and competence. The conceptual machinery of definitions and rules and laws all come together in the process of problem solving as nowhere else. Moreover, insofar as the problems reflect the realities of our world, the student learns a skill of immense practical value. This is no easy task; carrying out the analysis of even a moderately complex problem requires extraordinary intellectual vigilance and unflagging attention to detail above and beyond just "knowing how to do it." Like playing a musical instrument, the student must learn the basics and then practice, practice, practice. A single missed note in a sonata is overlookable; a single error in a calculation, however, can propagate through the entire effort producing an answer that's completely wrong. Getting it right is what *this* book is all about.

Although a selection of new problems has been added, the 9th-edition revision of this venerable text has concentrated on modernizing the work, and improving the pedagogy. To that end, the notation has been simplified and made consistent throughout. For example, force is now symbolized by F and only F; thus centripetal force is F_C, weight is F_W, tension is F_T, normal force is F_N, friction is F_f, and so on. Work (W) will never again be confused with weight (F_W), and period

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(T) will never be mistaken for tension (F_T). To better match what's usually written in the classroom, a vector is now indicated by a boldface symbol with a tiny arrow above it. The idea of significant figures is introduced (see Appendix A) and scrupulously adhered to in every problem. Almost all the definitions have been revised to make them more precise or to reflect a more modern perspective. Every drawing has been redrawn so that they are now more accurate, realistic, and readable.

If you have any comments about this edition, suggestions for the next edition, or favorite problems you'd like to share, send them to E. Hecht, Adelphi University, Physics Department, Garden City, NY 11530.

Freeport, NY EUGENE HECHT

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Chapter 1

Introduction to Vectors

A SCALAR QUANTITY, or *scalar*, is one that has nothing to do with spatial direction. Many physical concepts such as length, time, temperature, mass, density, charge, and volume are scalars; each has a scale or size, but no associated direction. The number of students in a class, the quantity of sugar in a jar, and the cost of a house are familiar scalar quantities.

Scalars are specified by ordinary numbers and add and subtract in the usual way. Two candies in one box plus seven in another give nine candies total.

A VECTOR QUANTITY is one that can be specified completely only if we provide both its magnitude (size) and direction. Many physical concepts such as displacement, velocity, acceleration, force, and momentum are vector quantities. For example, a *vector displacement* might be a change in position from a certain point to a second point 2 cm away and in the x-direction from the first point. As another example, a cord pulling northward on a post gives rise to a *vector force* on the post of 20 newtons (N) northward. One newton is 0.225 pound (1.00 N = 0.225 lb). Similarly, a car moving south at 40 km/h has a *vector velocity* of 40 km/h-SOUTH.

A vector quantity can be represented by an arrow drawn to scale. The length of the arrow is proportional to the magnitude of the vector quantity (2 cm, 20 N, 40 km/h in the above examples). The direction of the arrow represents the direction of the vector quantity.

In printed material, vectors are often represented by boldface type, such as **F**. When written by hand, the designations $\vec{F}$ and $\underset{\sim}{F}$ are commonly used. A vector is not completely defined until we establish some rules for its behavior.

THE RESULTANT, or sum, of a number of vectors of a particular type (force vectors, for example) is that single vector that would have the same effect as all the original vectors taken together.

GRAPHICAL ADDITION OF VECTORS (POLYGON METHOD): This method for finding the resultant $\vec{R}$ of several vectors ($\vec{A}$, $\vec{B}$, and $\vec{C}$) consists in beginning at any convenient point and drawing (to scale and in the proper directions) each vector arrow in turn. They may be taken in any order of succession: $\vec{A}+\vec{B}+\vec{C}=\vec{C}+\vec{A}+\vec{B}=\vec{R}$. The tail end of each arrow is positioned at the tip end of the preceding one, as shown in Fig. 1-1.

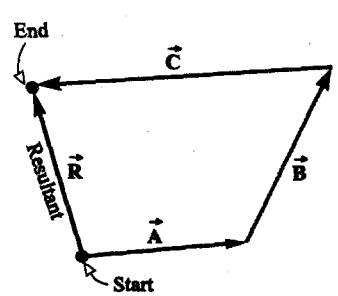

Fig. 1-1

The resultant is represented by an arrow with its tail end at the starting point and its tip end at the tip of the last vector added. If $\vec{\mathbf{R}}$ is the resultant, $R = |\vec{\mathbf{R}}|$ is the size or *magnitude* of the resultant.

PARALLELOGRAM METHOD for adding two vectors: The resultant of two vectors acting at any angle may be represented by the diagonal of a parallelogram. The two vectors are drawn as the sides of the parallelogram and the resultant is its diagonal, as shown in Fig. 1-2. The direction of the resultant is away from the origin of the two vectors.

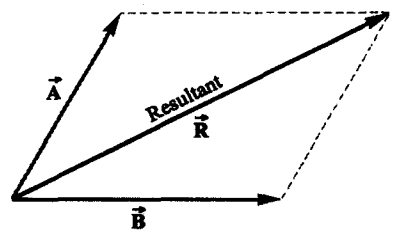

Fig. 1-2

SUBTRACTION OF VECTORS: To subtract a vector $\vec{\mathbf{B}}$ from a vector $\vec{\mathbf{A}}$, reverse the direction of $\vec{\mathbf{B}}$ and add individually to vector $\vec{\mathbf{A}}$, that is, $\vec{\mathbf{A}} - \vec{\mathbf{B}} = \vec{\mathbf{A}} + (-\vec{\mathbf{B}})$.

THE TRIGONOMETRIC FUNCTIONS are defined in relation to a right angle. For the right triangle shown in Fig. 1-3, by definition

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{B}{C}, \quad \cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{A}{C}, \quad \tan\theta = \frac{\text{opposite}}{\text{adjacent}} = \frac{B}{A}$$

We often use these in the forms

$$B = C\sin\theta \qquad A = C\cos\theta \qquad B = A\tan\theta$$

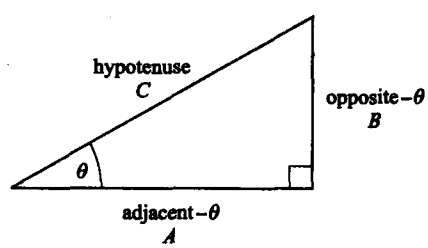

Fig. 1-3

A COMPONENT OF A VECTOR is its effective value in a given direction. For example, the x-component of a displacement is the displacement parallel to the x-axis caused by the given displacement. A vector in three dimensions may be considered as the resultant of its component vectors resolved along any three *mutually perpendicular* directions. Similarly, a vector in two dimensions

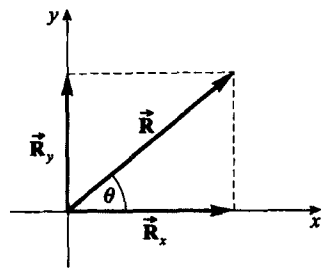

Fig. 1-4

may be resolved into two component vectors acting along any two mutually perpendicular directions. Figure 1-4 shows the vector $\vec{R}$ and its x and y vector components, $\vec{R}_x$ and $\vec{R}_y$, which have magnitudes

$$|\vec{R}_x| = |\vec{R}| \cos\theta \qquad \text{and} \qquad |\vec{R}_y| = |\vec{R}| \sin\theta$$

or equivalently

$$R_x = R\cos\theta \qquad \text{and} \qquad R_y = R\sin\theta$$

COMPONENT METHOD FOR ADDING VECTORS: Each vector is resolved into its x-, y-, and z-components, with negatively directed components taken as negative. The scalar x-component R_x of the resultant $\vec{R}$ is the algebraic sum of all the scalar x-components. The scalar y- and z-components of the resultant are found in a similar way. With the components known, the magnitude of the resultant is given by

$$R = \sqrt{R_x^2 + R_y^2 + R_z^2}$$

In two dimensions, the angle of the resultant with the x-axis can be found from the relation

$$\tan\theta = \frac{R_y}{R_x}$$

UNIT VECTORS have a magnitude of one and are represented by a boldface symbol topped with a caret. The special unit vectors $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$, and $\hat{\mathbf{k}}$ are assigned to the x-, y-, and z-axes, respectively. A vector $3\hat{\mathbf{i}}$ represents a three-unit vector in the $+x$-direction, while $-5\hat{\mathbf{k}}$ represents a five-unit vector in the $-z$-direction. A vector $\vec{R}$ that has scalar x-, y-, and z-components R_x, R_y, and R_z, respectively, can be written as $\vec{R} = R_x\hat{\mathbf{i}} + R_y\hat{\mathbf{j}} + R_z\hat{\mathbf{k}}$.

THE DISPLACEMENT: When an object moves from one point in space to another the displacement is the vector from the initial location to the final location. It is independent of the actual distance traveled.

Solved Problems

1.1 Using the graphical method, find the resultant of the following two displacements: 2.0 m at 40° and 4.0 m at 127°, the angles being taken relative to the $+x$-axis, as is customary. Give your answer to two significant figures. (See Appendix A on significant figures.)

Choose x- and y-axes as shown in Fig. 1-5 and lay out the displacements to scale, tip to tail from the origin. Notice that all angles are measured from the $+x$-axis. The resultant vector $\vec{\mathbf{R}}$ points from starting point to end point as shown. We measure its length on the scale diagram to find its magnitude, 4.6 m. Using a protractor, we measure its angle θ to be 101°. The resultant displacement is therefore 4.6 m at 101°.

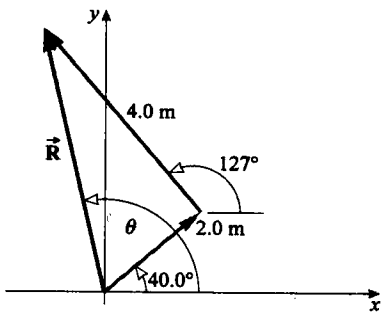

Fig. 1-5

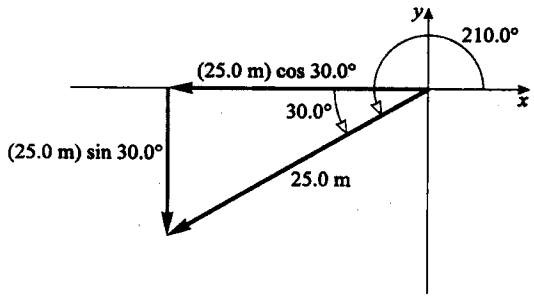

Fig. 1-6

1.2 Find the x- and y-components of a 25.0-m displacement at an angle of 210.0°.

The vector displacement and its components are shown in Fig. 1-6. The scalar components are

$$x\text{-component} = -(25.0\text{ m})\cos 30.0° = -21.7\text{ m}$$
$$y\text{-component} = -(25.0\text{ m})\sin 30.0° = -12.5\text{ m}$$

Notice in particular that each component points in the negative coordinate direction and must therefore be taken as negative.

1.3 Solve Problem 1.1 by use of rectangular components.

We resolve each vector into rectangular components as shown in Fig. 1-7(a) and (b). (Place a cross-hatch symbol on the original vector to show that it is replaced by its components.) The resultant has scalar components of

$$R_x = 1.53\text{ m} - 2.41\text{ m} = -0.88\text{ m} \qquad R_y = 1.29\text{ m} + 3.19\text{ m} = 4.48\text{ m}$$

Notice that components pointing in the negative direction must be assigned a negative value.

The resultant is shown in Fig. 1.7(c); there, we see that

$$R = \sqrt{(0.88\text{ m})^2 + (4.48\text{ m})^2} = 4.6\text{ m} \qquad \tan\phi = \frac{4.48\text{ m}}{0.88\text{ m}}$$

and $\phi = 79°$, from which $\theta = 180° - \phi = 101°$. Hence $\vec{\mathbf{R}} = 4.6\text{ m} — 101°$ FROM $+x$-AXIS; remember vectors must have their directions stated explicitly.

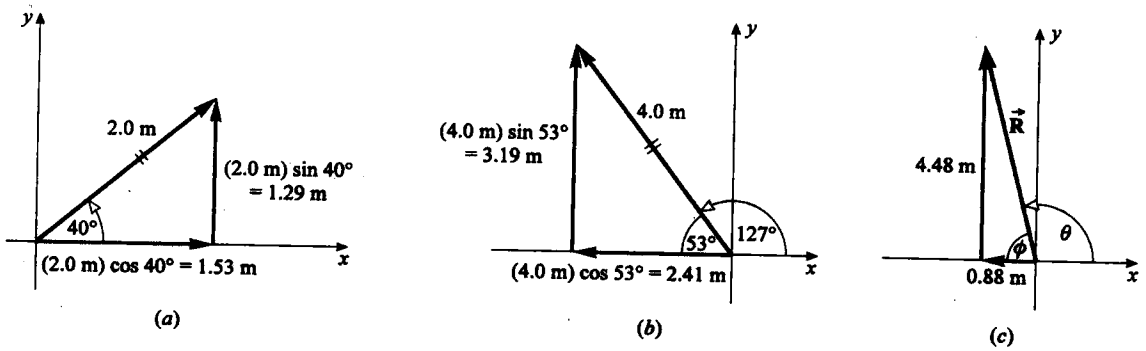

Fig. 1-7

1.4 Add the following two force vectors by use of the parallelogram method: 30 N at 30° and 20 N at 140°. Remember that numbers like 30 N and 20 N have two significant figures.

The force vectors are shown in Fig. 1-8(*a*). We construct a parallelogram using them as sides, as shown in Fig. 1-8(*b*). The resultant $\vec{\mathbf{R}}$ is then represented by the diagonal. By measurement, we find that $\vec{\mathbf{R}}$ is 30 N at 72°.

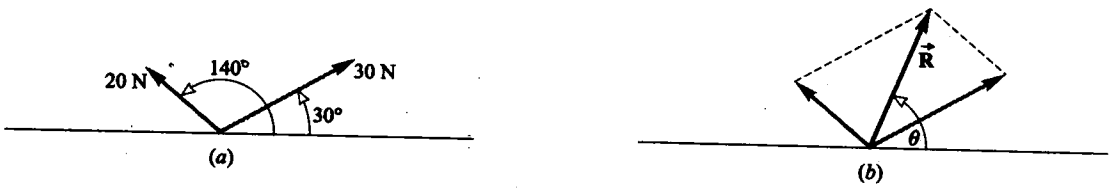

Fig. 1-8

1.5 Four coplanar forces act on a body at point O as shown in Fig. 1-9(*a*). Find their resultant graphically.

Starting from O, the four vectors are plotted in turn as shown in Fig. 1-9(*b*). We place the tail end of each vector at the tip end of the preceding one. The arrow from O to the tip of the last vector represents the resultant of the vectors.

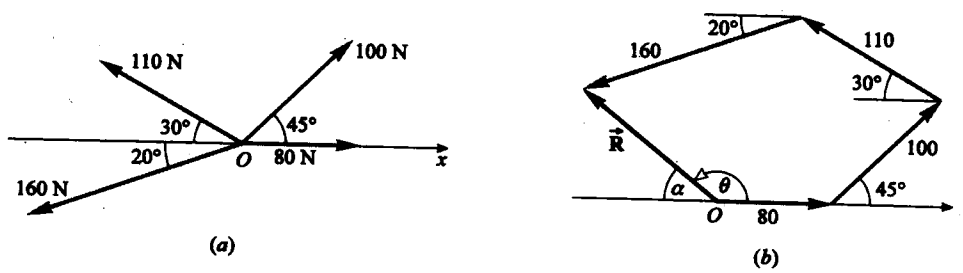

Fig. 1-9

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