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SCHAUM'S OUTLINE OF

THEORY AND PROBLEMS

of

PHYSICAL SCIENCE

by

ARTHUR BEISER, Ph.D.

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Preface

This book is intended to provide students of physical science with help in mastering elementary physics, chemistry, earth science, and astronomy. A wide spectrum of topics is covered, so that the reader may select those which correspond to his particular needs. Both SI (metric) and British units are used.

Each chapter begins with an outline of its subject. The solved problems that follow are of two kinds: those that show how numerical answers are obtained to typical questions in physics and chemistry, and those that review important facts and ideas in all the physical sciences. The supplementary problems give the reader both a chance for practice and a means to gauge his progress.

ARTHUR BEISER

November 1974

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Chapter 1

Physical Quantities

POWERS OF TEN

Very small and very large numbers are common in physical science and are best expressed with the help of powers of 10. Any number in decimal form can be written as a number between 1 and 10 multiplied by a power of 10:

$$834 = 8.34 \times 10^2 \qquad 0.00072 = 7.2 \times 10^{-4}$$

The powers of 10 from 10^{-6} to 10^6 are as follows:

$10^0 = 1 = 1$ with decimal point moved 0 places
$10^{-1} = 0.1 = 1$ with decimal point moved 1 place to the left
$10^{-2} = 0.01 = 1$ with decimal point moved 2 places to the left
$10^{-3} = 0.001 = 1$ with decimal point moved 3 places to the left
$10^{-4} = 0.0001 = 1$ with decimal point moved 4 places to the left
$10^{-5} = 0.00001 = 1$ with decimal point moved 5 places to the left
$10^{-6} = 0.000001 = 1$ with decimal point moved 6 places to the left

$10^0 = 1 = 1$ with decimal point moved 0 places
$10^1 = 10 = 1$ with decimal point moved 1 place to the right
$10^2 = 100 = 1$ with decimal point moved 2 places to the right
$10^3 = 1000 = 1$ with decimal point moved 3 places to the right
$10^4 = 10{,}000 = 1$ with decimal point moved 4 places to the right
$10^5 = 100{,}000 = 1$ with decimal point moved 5 places to the right
$10^6 = 1{,}000{,}000 = 1$ with decimal point moved 6 places to the right

CALCULATIONS USING POWERS OF TEN

When numbers written in powers-of-10 notation are to be added or subtracted, they must all be expressed in terms of the *same* power of 10:

$$3 \times 10^2 + 4 \times 10^3 = 0.3 \times 10^3 + 4 \times 10^3 = 4.3 \times 10^3$$

To multiply two powers of 10, add their exponents; to divide one power of 10 by another, subtract the exponent of the latter from that of the former:

$$10^n \times 10^m = 10^{n+m} \qquad \frac{10^n}{10^m} = 10^{n-m}$$

Reciprocals follow the pattern

$$\frac{1}{10^n} = 10^{-n}$$

The rules for finding powers and roots of powers of 10 are

$$(10^n)^m = 10^{n \times m} \qquad \sqrt[m]{10^n} = (10^n)^{1/m} = 10^{n/m}$$

In taking the mth root, the power of 10 should be chosen to be a multiple of m. Thus

$$\sqrt{10^{15}} = \sqrt{10} \times \sqrt{10^{14}} = \sqrt{10} \times 10^7 = 3.16 \times 10^7$$

UNITS

Some common British and SI (metric) units of length and time are

LENGTH

1 foot (ft) = 12 in. = 0.305 m

1 inch (in.) = 0.083 ft = 2.54 cm

1 statute mile (mi) = 5280 ft = 1.61 km

1 meter = 100 cm = 39.4 in. = 3.28 ft

1 centimeter (cm) = 0.01 m = 0.394 in.

1 kilometer (km) = 1000 m = 0.621 mi

TIME

1 minute (min) = 60 seconds (s)

1 hour (hr) = 60 min = 3600 s

1 day = 24 hr = 86,400 s

Subdivisions and multiples of metric units are designated by prefixes according to the corresponding power of 10.

Prefix	Power	Abbreviation	Example
pico-	10^{-12}	p	1 pf = 1 picofarad = 10^{-12} farad
nano-	10^{-9}	n	1 ns = 1 nanosecond = 10^{-9} second
micro-	10^{-6}	μ	1 μA = 1 microampere = 10^{-6} ampere
milli-	10^{-3}	m	1 mm = 1 millimeter = 10^{-3} meter
centi-	10^{-2}	c	1 cl = 1 centiliter = 10^{-2} liter
kilo-	10^{3}	k	1 kg = 1 kilogram = 10^{3} grams
mega-	10^{6}	M	1 MW = 1 megawatt = 10^{6} watts
giga-	10^{9}	G	1 GeV = 1 gigaelectron-volt = 10^{9} electron volts

CONVERTING UNITS

Units are algebraic quantities and may be multiplied and divided by one another. To convert a quantity expressed in a certain unit to its equivalent in a different unit of the same kind, we use the fact that multiplying or dividing anything by 1 does not affect its value. For instance, 12 in. = 1 ft, so 12 in./ft = 1, and we can convert a length s expressed in ft to its value in inches by multiplying s by 12 in./ft:

$$4 \text{ ft} = 4 \cancel{\text{ft}} \times 12 \frac{\text{in.}}{\cancel{\text{ft}}} = 48 \text{ in.}$$

SCALAR AND VECTOR QUANTITIES

A *scalar quantity* has only magnitude and is completely specified by a number and a unit. Examples are mass (a stone has a mass of 2 kg), volume (a bottle has a volume of 12 oz), and frequency (house current has a frequency of 60 cycles/s). Symbols of scalar quantities are printed in italic type (m = mass, V = volume). Scalar quantities of the same kind are added using ordinary arithmetic.

A *vector quantity* has both magnitude and direction. Examples are displacement (an airplane has flown 200 mi to the southwest), velocity (a car is moving at 60 mi/hr to the north), and force (a man applies an upward force of 15 lb to a package). Symbols of vector quantities are printed in boldface type ($\mathbf{v}$ = velocity, $\mathbf{F}$ = force) and expressed in handwriting by arrows over the letters ($\vec{v}$, $\vec{F}$). The magnitude of a vector quantity is printed in italic type (F is the magnitude of the force $\mathbf{F}$). When vector quantities are added, their directions must be taken into account.

VECTOR ADDITION

A *vector* is an arrowed line whose length is proportional to a certain vector quantity and whose direction indicates the direction of the quantity.

To add the vector **B** to the vector **A**, draw **B** so that its tail is at the head of **A**. The vector sum **A** + **B** is the vector **R** that joins the tail of **A** and the head of **B** (Fig. 1-1). **R** is usually called the *resultant* of **A** and **B**.

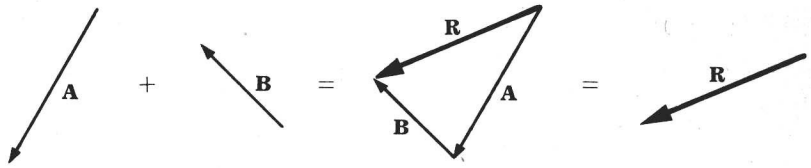

Fig. 1-1

The order in which **A** and **B** are added is not significant, so that **A** + **B** = **B** + **A** (Figs. 1-1 and 1-2).

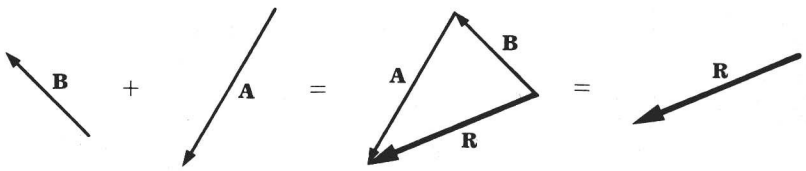

Fig. 1-2

Exactly the same procedure is followed when more than two vectors of the same kind are to be added. The vectors are strung together head to tail (being careful to preserve their correct lengths and directions), and the resultant **R** is the vector drawn from the tail of the first vector to the head of the last. The order in which the vectors are added does not matter (Fig. 1-3).

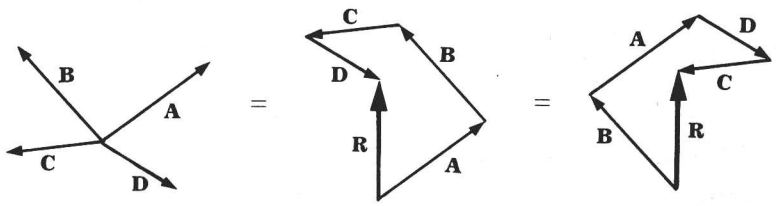

Fig. 1-3

Solved Problems

1.1. Examples of powers-of-10 notation.

$$20 = 2 \times 10 = 2 \times 10^1$$

$$3043 = 3.043 \times 1000 = 3.043 \times 10^3$$

$$8{,}700{,}000 = 8.7 \times 1{,}000{,}000 = 8.7 \times 10^6$$

$$0.22 = 2.2 \times 0.1 = 2.2 \times 10^{-1}$$

$$0.000035 = 3.5 \times 0.00001 = 3.5 \times 10^{-5}$$

1.2. Examples of addition and subtraction.

$$6\times10^{2} + 5\times10^{4} = 0.06\times10^{4} + 5\times10^{4} = 5.06\times10^{4}$$

$$2\times10^{-2} + 3\times10^{-3} = 2\times10^{-2} + 0.3\times10^{-2} = 2.3\times10^{-2}$$

$$7 + 2\times10^{-2} = 7 + 0.02 = 7.02$$

$$6\times10^{4} - 4\times10^{2} = 6\times10^{4} - 0.04\times10^{4} = 5.96\times10^{4}$$

$$3\times10^{-2} - 5\times10^{-3} = 3\times10^{-2} - 0.5\times10^{-2} = 2.5\times10^{-2}$$

$$7\times10^{-5} - 2\times10^{-4} = 0.7\times10^{-4} - 2\times10^{-4} = -1.3\times10^{-4}$$

$$6.23\times10^{-3} - 6.28\times10^{-3} = -0.05\times10^{-3} = -5\times10^{-5}$$

1.3. Examples of multiplication and division.

$$10^{5}\times10^{-2} = 10^{5-2} = 10^{3} \qquad \frac{10^{4}}{10^{-3}} = 10^{4-(-3)} = 10^{4+3} = 10^{7}$$

$$\frac{10^{3}}{10^{6}} = 10^{3-6} = 10^{-3} \qquad \frac{10^{5}\times10^{-7}}{10^{2}} = 10^{5-7-2} = 10^{-4}$$

1.4. A sample calculation.

$$\frac{460\times0.00003\times100{,}000}{9000\times0.0062} = \frac{(4.6\times10^{2})\times(3\times10^{-5})\times(10^{5})}{(9\times10^{3})\times(6.2\times10^{-3})}$$

$$= \frac{4.6\times3}{9\times6.2}\times\frac{10^{2}\times10^{-5}\times10^{5}}{10^{3}\times10^{-3}}$$

$$= 0.25\times\frac{10^{2-5+5}}{10^{3-3}} = 0.25\times\frac{10^{2}}{10^{0}} = 25$$

1.5. Examples of powers of numbers.

$$(10^{2})^{4} = 10^{2\times4} = 10^{8}$$

$$(10^{-3})^{5} = 10^{-3\times5} = 10^{-15}$$

$$(10^{-4})^{-3} = 10^{-4\times-3} = 10^{12}$$

$$(3\times10^{3})^{2} = 3^{2}\times(10^{3})^{2} = 9\times10^{6}$$

$$(4\times10^{-5})^{3} = 4^{3}\times(10^{-5})^{3} = 64\times10^{-15} = 6.4\times10^{-14}$$

$$(2\times10^{-2})^{-4} = \frac{1}{2^{4}}\times(10^{-2})^{-4} = \frac{1}{16}\times10^{8} = 0.0625\times10^{8} = 6.25\times10^{6}$$

1.6. Examples of square roots.

Even powers of 10:

$$\sqrt{10^{6}} = 10^{6/2} = 10^{3}$$

$$\sqrt{5\times10^{4}} = \sqrt{5}\times\sqrt{10^{4}} = 2.24\times10^{2}$$

Odd powers of 10:

$$\sqrt{3\times10^{5}} = \sqrt{30\times10^{4}} = \sqrt{30}\times\sqrt{10^{4}} = 5.48\times10^{2}$$

$$\sqrt{0.000025} = \sqrt{2.5\times10^{-5}} = \sqrt{25\times10^{-6}} = \sqrt{25}\times\sqrt{10^{-6}} = 5\times10^{-3}$$

1.7. Examples of cube roots.

$$\sqrt[3]{10^{9}} = 10^{9/3} = 10^{3}$$

$$\sqrt[3]{10^{8}} = \sqrt[3]{10^{2}\times10^{6}} = \sqrt[3]{100}\times\sqrt[3]{10^{6}} = 4.64\times10^{2}$$

$$\sqrt[3]{3.8\times10^{19}} = \sqrt[3]{38\times10^{18}} = \sqrt[3]{38}\times\sqrt[3]{10^{18}} = 3.36\times10^{6}$$

$$\sqrt[3]{2.7\times10^{-5}} = \sqrt[3]{27\times10^{-6}} = \sqrt[3]{27}\times\sqrt[3]{10^{-6}} = 3\times10^{-2}$$