a miniature crater as at *b*, *c*, *d*. But the crater vent becoming intermittently choked, the accumulation of gas beneath the crust caused the liquid "lava" to rise through any neighbouring holes as at *e*, *f*, giving rise to a ring crater. The pressure of the accumulated gas now drove out the obstruction in *a*, when the liquid lava receded in *e* as at *g*. This intermittent action went on till the crater *i* was built up—entirely by "rise and fall" (as of a tide), no gas escaping at this hole.

In the case of the moon the rise and fall would be caused by the tidal motion of the still liquid interior. The solid crust would resist the periodic rise of the liquid interior, and the liquid would well through the crust and recede again as the wave passed.

When the crust was thin, and the lava very liquid, the large ring structures would be formed, as the lava would flow far; but

FIG. 2.

as the crust got thicker and the lava more viscid, the more striking craters like Copernicus would be built up. When the vent was very small, or the lava very viscid, the exuded lava would build up mountain ranges, or peaks like Pico, as it could not flow far, and would be cooled too much to allow of its flowing back with the ebb tide.

The existence of the cause proposed by Messrs. Nasmyth and Carpenter, viz., expansion on solidification, is very doubtful. The proof they adduced was that a piece of solid slag would float on liquid slag. But when slag solidifies it becomes filled with small cracks, which doubtless contain air, and so aid in the flotation. When I was working at this subject I had some slag poured into an iron mould kept cool by immersion in water. When the slag had cooled a distinct depression was seen on the upper free surface, showing that the slag had contracted during solidification. No doubt its contraction or expansion will depend upon its composition, and we do not know the composition of the moon's surface, but we need not depend upon a doubtful property for an explanation when a set of conditions have existed which must have yielded an ample force for the production of the observed results.

In the photograph marked Fig. 2, at *a* can be seen a crater

with a raised floor and a central cone, at *b* a crater filled to the lip like "Wargentín," while on the plain near *b*, and round the open crater *c*, will be seen numerous minute craters, as on the moon's surface in the neighbourhood of "Aristotle" or "Copernicus," while in other photographs are seen walled plains like the "Mare Crisium," so that all the important features of lunar topography are reproduced in this slag, and there are many minor points of agreement which cannot be gone into in the limits of a letter.

Although I have always considered the tides the cause of the wonderful lunar configuration, I was not satisfied that that cause alone was of sufficient magnitude, till the work of Mr. Darwin placed the matter in such a clear light that I now venture to submit the idea to your readers as a feasible explanation of the familiar lunar features.

J. B. HANNAY.

On the Need of a New Geometrical Term—"Conjugate Angles."

IN geometrical discussions, such as arise out of a great variety of physical problems, it is frequently necessary to refer to an acute or obtuse angle *A* as being equal to another acute or obtuse angle *B*, because contained by two straight lines which are respectively perpendicular to those containing the angle *B*. Such a statement of the reason of the equality is, however, cumbersome. Sometimes, indeed, such angles when acute might be described as equal because they are the complements of equal (because vertically opposite) angles; but it will often happen that the figure does not show the vertically opposite angles that would be referred to.

I should be glad to know whether there is any term expressing the relation in question in use among either English or foreign writers, and, in default of such, would suggest that such angles be called *conjugate*, or if greater precision is required, *rectangularly conjugate*, the general term *conjugate* to be used when we wish to refer to an angle *A* as equal to an angle *B* because contained by sides whose directions are the directions of the sides of *B*, after each has experienced an equal and similar rotation in the plane of the diagram, whether the rotation is through a right angle or not.

The shorter inclusive term *conjugate* could always be used for the less general but longer term *rectangularly conjugate*, when brevity was aimed at.

A. M. WORTHINGTON.

R.N.E. College, Devonport, October 30.

Printing Mathematics.

THE main features of mathematical work that give trouble in printing are three: the expressing of (1) fractions, (2) powers, (3) roots.

(1) To simplify the expression of fractions we have the solidus suggested by Sir G. Stokes. But the solidus has been hitherto much less used than it might be, on account of the uncertainty as to how far its influence reaches in any expression more complicated than the simplest fractions. This uncertainty can easily be removed, and the usefulness of the solidus greatly extended by defining more definitely its exact meaning. This is done in the simple conventions proposed below.

(2) To express the process of involution, the sign $\wedge$, suggested by Mr. C. T. Mitchell in the *Electrician*, is more concise and clearer than that mentioned by Prof. S. P. Thompson in *NATURE*. And Mr. Mitchell's sign, if defined by conventions similar to those applied below to the solidus, is capable of a like extensive application.

(3) To express roots we have the sign $\sqrt{}$. But, when accompanied by a horizontal line above to show the extent of its influence, this sign also requires special spacing. But it can be brought into line with the rest by the use of the same conventions.

Taking then for

<i>a.</i>	the sign of division	...	...	...	$\div$
<i>b.</i>	" " involution	...	...	...	$\wedge$
<i>c.</i>	" " evolution	...	...	...	$\sqrt{}$

we may use each of these signs in either of two ways:—

I. Simply as a sign of operation, in which case it can influence only the quantities immediately adjacent to it.

II. In a double capacity—

(1) As a sign of operation.

(2) As one end of a bracket, of which the other end is |. This bracketing influence may be directed either forwards or backwards, or both ways at once.

Examples.

a. Division.

$$\begin{aligned} \frac{a+b}{c} + d &= | a + b/c + d, \\ a + \frac{b}{c+d} &= a + b/c + d |, \\ \frac{a+b}{c+d} &= | a + b/c + d |, \\ a \cdot \frac{b}{c} \cdot d &= ab/cd, \quad a \cdot \frac{b}{cd} = ab/cd |, \\ \frac{a}{b+c} (d+e) &= a/(b+c)(d+e), \\ \frac{a}{(b+c)(d+e)} &= a/(b+c)(d+e) |, \\ \sin \frac{\theta}{n} &= \sin \theta/n, \quad \frac{\sin \theta}{n} = | \sin \theta/n. \end{aligned}$$

Continued fractions also can readily be brought into one line by this notation—

$$\frac{a}{b + \frac{c}{d + \frac{e}{f}}} = | a/b + c/(d+e) + f/g |,$$

B. Involution.

$$\begin{aligned} a^b &= a \setminus b, \quad a^{-b} = a \setminus -b, \\ (a+b)^c + d &= | a + b \setminus c + d, \\ a + b^{c+d} &= a + b \setminus c + d |, \\ (a+b)^{c+d} &= | a + b \setminus c + d |, \\ (a+b)^{c+d} &= | a + b \setminus | c + d / e + f |. \end{aligned}$$

$a \setminus b/c$ and $a/b \setminus c$ are ambiguous, but $| a \setminus b/c = \frac{a^b}{c}$, because | being unnecessary for $\setminus$ in this case, can apply only to $\frac{(a+b)^c}{d}$ is $| a + b \setminus c/d$, two vertical lines being required.

Similarly $| a/b \setminus c = \left(\frac{a}{b}\right)^c$, $a/b \setminus c = \frac{a}{b^c}$, $a \setminus b/c = \frac{a^b}{c}$

$$a \setminus b \setminus c \setminus d = \frac{a^b}{c^d}.$$

γ. Evolution—

$$\begin{aligned} \sqrt[n]{a+b+c} &= | n \sqrt{a+b+c} |, \\ \sqrt[n]{a+b} / \sqrt{c+d} &= | a + b \sqrt{c+d} |, \\ \sqrt[n]{a+b} / \sqrt{c+d} &= | a + b \sqrt{c+d}, \\ a + b \cdot \sqrt{c+d} &= a + b \sqrt{c+d} |, \\ a + \sqrt{b} / \sqrt{c+d} &= a + | b \sqrt{c+d}. \end{aligned}$$

In some cases lines of differing thickness might be advisable; for instance—

$$\frac{b^{\frac{1}{2}}}{c(d+e)^3} = | b \setminus 1/2 | / c | d+e \setminus 3 |.$$

There are many other ways in which this notation might be used; but the above will suffice to illustrate the advantages of it. And these advantages are substantial. It enables the work to be printed in the same space as ordinary letterpress, and thus avoids the special spacing, from which nine-tenths of the troubles in mathematical printing arise. It requires no new types, except, perhaps, $\setminus$, and each of the signs used is suggestive of the original mode of writing for which it is a substitute. It can be used without confusion in conjunction with all ordinary brackets. How far this notation would suit very complicated expressions, is a point that would have to be determined by experience; but for printing mathematics of ordinary complexity it would be useful in economizing space and diminishing the risk of printers' errors without any sacrifice of clearness.

Cambridge, October 27.

W. CASSIE.

NO. 1201, VOL. 47]

"Sunshine."

IN acknowledging the courteous criticism and the kind remarks which "C. V. B." has been pleased to make about my little book, may I be permitted to comment on one or two points, which I think he has imperfectly understood from the text. We all know that when "C. V. B." undertakes to review a book, he does his work in a thorough and searching manner, and from his critique it is evident that "Sunshine" has been well read. Notwithstanding this, in one or two of the instances selected for criticism the meaning, at once simple and obvious to a little child, who neither knows nor suspects any other, seems to have missed him, presumably because he knows all the bearings of the subject. Thus it is sometimes a disadvantage to be learned. Of this I propose presently to give an instance in the order which it occurs.

After poking fun at me, because, the "Sunshine" course being ended, Tommy meets King Sol face to face and "has it out with him," my critic proceeds to discuss the limits within which the imagination may be appealed to as a factor in scientific education, and while I agree with him in the main, I am tempted in passing to remind him of what Tyndall terms "the scientific use of the imagination," to which the clearness and (to me) the charm of his own lectures is largely due. Be that as it may, in one of "Nature's Story Books" I feel fully justified in employing, *within the limits of scientific accuracy*, any or all of the powers of the mind, which shall help children and others to realize the relation they bear to their surroundings, assured that in a course based upon some hundreds of experiments synthetically worked out and deductions made—a course whose main object is to lead children to go direct to Nature, *via* experiment, for their knowledge, there is little danger that the imagination be cultivated at the expense of the reasoning faculties. The experience of the writer is that the children attending the lectures became extremely critical—a state of mind which, although of inestimable value in acquiring knowledge, is not one of the happiest in other respects. Therefore it was thought desirable to provide them with some necessary ballast, and this is my defence of the hypnotic visit to the moon, and the other two chapters to which the critic alludes.

Natural science apart, it seems to me that the tendency of the school-teaching of to-day is calculated rather to make children hard and matter of fact. For this reason I have endeavoured in these Sunshine Stories to interest children in the poetry of their common lives, myself playing somewhat the rôle of an optical instrument, presenting images sometimes real, sometimes virtual of those physical beauties which touch them at every point. The fact that "C. V. B." recognizes in "Sunshine" the realism which the "picturesque language" was intended to convey, disposes of the case of my Cape Town reviewer, who mildly insinuates that I have been guilty of some fraud upon little children in calling "Sunshine" a story-book. Therefore I am the more glad that "C. V. B." agrees with me that the mathematical side of these questions should not be obtruded. There are so many excellent text-books which supply that information for older pupils. I need not say that I shall be most happy to add the exception in the case of the rainbow. I thank him also for pointing out a passage in the notes where an additional clause is necessary, owing to the transposition of a paragraph. But I take exception to the statement about the top, for it is evident that the experiment is not made under the same conditions as that which "C. V. B." has in mind, because my boys get green and he gets (he says) white, or nearly white. The home experiment reads: "I am giving each of you squares of coloured paper to take home . . . then you may have the papers to put on your tops—e.g., cover half blue and half yellow, spin the top and you will see green." A note on page 341 refers to the kind of paper. Now it seems to me from the expression "painted disc," which "C. V. B." has made use of, that possibly he may have had Clerk Maxwell's top in mind when he wrote.

When I say to a boy, "Here are two squares of paper, one blue and one yellow; when you've done so and so, you can have the paper to keep—cover your top, half yellow, half blue, &c." the lad understands me, and when I am not there he takes out his halfpenny whip-top, tears a piece of the blue paper, and rendering it slightly adhesive hammers it down on the top with his right fist; he tears a similar piece and treats it in the same way, and so on until he has covered half. Then he takes the yellow paper and covers the other half with irregular patches of yellow. He spins the top and sees green.