in many cases returns when the pressure is relieved. The appearance then suggests a lamp alternately extinguished and relit.

The same precautions as to the smallness of the test-pieces and the absence of a comparatively soft bed under the coloured layer have to be observed in the case of metallic feathers.

The colours of anilin films are not affected by pressure otherwise than by the optical contact between them and the upper quartz lens.

The same may be said of the colours of tempered steel, etc. A simple experiment is to heat a piece of polished steel and to remove by polishing a narrow band of the coloured part. Then form a series of Newton's rings, having this band as a diameter. It will be found that in the straw-yellow of the tempered part the rings are scarcely displaced as they cross the band. Further, it may be noticed that when any of the colours are gradually polished off the colour does not change as the thickness of the layer is reduced but merely becomes fainter.

From this it may be gathered that the colours of tempering are not due to interference, at any rate in the ordinary sense in which the word is used.

A. MALLOCK.

The Tendency of Elongated Bodies to Set in the North and South Direction.

THE letters of Sir Arthur Schuster and Col. E. H. Grove-Hills in NATURE of October 20 and November 24 under the above heading are interesting, as is also the article by Mr. W. D. Lambert in the *American Journal of Science* for September last, to which reference is made by the latter, but the extremely weak gravitational force dealt with cannot possibly have any appreciable effect on my apparatus, and is certainly quite inadequate to account for the results of experiments made with it. Indeed, I gather from some of Sir Arthur Schuster's remarks that he feels that this is the case. The force that I have found to exist is another altogether, as I am confident anyone who has watched the experiments under favourable conditions would admit.

Mr. Lambert in his article is referring to a suspended rod of 40 cm. length, weighted at both ends, and finds for this that the force was only $1/400,000$ th of a dyne or $1/400,000,000$ th of a gram. Now, what conceivable effect can such a force have on a vertically suspended circular ring or disc of the thinnest paper, or other light material, of only $3\frac{1}{2}$ cm. diameter? And yet it is with these that some of the most decisive results of my experiments have been obtained. Under favourable conditions the N. and S. directive force acting on the disc is by no means insignificant, and, indeed, when the sky is clear, the barometer high and steady, and there is no wind, it is frequently strong enough, when the apparatus is placed on high level ground in the open, to cause the disc to come to rest in the true N. and S. direction in less than five minutes, or to oscillate fairly rapidly (about five seconds interval) a few degrees on either side of this line. Moreover, other conditions are inconsistent with any purely gravitational theory being the explanation. I have used both suspended discs and pointers floating on paraffin oil, and obtained about the same results from both; not that one gives the E. and W. direction and the other the N. and S. The only difference noticed was that the floating pointer took longer to come to the N. and S. line. Further, it is not necessarily the elongated diameter that turns N. and S., as Sir

Arthur Schuster assumes. For instance, if a strip of aluminium about 1 in. wide is coiled round into the form of a ring and then flattened so that the sides almost touch each other, when suspended vertically the flat-surface sides turn N. and S., as in the case of the ordinary discs. Now, if these flat surfaces are pulled out so as to form a ring with the elongated horizontal diameter several times as long as the breadth of the strip, it is not this elongated diameter that turns N. and S., but the surface breadth of the strip as before. In fact, there is no alteration in the direction, but the surface sides of the aluminium strip take up the same direction as when they were flattened close together.

In rainy weather, or when the sky is clouded or the barometer is falling, no satisfactory results can be obtained, and the disc will then usually turn approximately towards the bearing of the thickest clouds. From repeated experiments it has been found that when the apparatus is placed in an iron bucket covered with an iron lid, the N. and S. directive force ceases to act upon the disc, although it may be fairly strong in the open at the same time. The force appears to be strongest in still, frosty weather, when the sky is clear, even though there may be some ground mist.

Since the apparatus was exhibited at the Royal Society's conversazione in May of last year many more experiments have been made by observers in different parts of the world, extending from Spitsbergen in latitude 80° N. to the top of the Cameroon Mountain (13,353 ft.) close to the equator, and from Canada and the United States to the Red Sea, all of which give much the same results that I and others have obtained in this country; so whatever may happen in other parts, there can be no doubt that over this wide area of the earth's surface this N. and S. directive force does exist. In one or two other cases the results have been indefinite, owing apparently to the observers having no proper apparatus or the weather conditions being unfavourable. It is perhaps too early yet to speak positively about the nature of this N. and S. directive force, but the conclusion I have come to is that, in the main, it must be electric, and is probably due to the earth rotating in an electric field.

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Table for the Duration of Sunset.

THE subjoined table was made thus:—From Table VI. in the *American Nautical Almanac*, for each date and latitude indicated, the hour of sunset on the meridian of Greenwich is taken and corrected for equation of time, giving an hour-angle precise within 1 m. or 15' (as both local mean time and equation of time are rounded off to the nearest minute). From latitude, declination, and this hour-angle the semi-duration of sunset in arc minutes is computed by the differential formula,

$$(1) \quad dP_s = \cos h \, dh / \cos \phi \cos \delta \sin P_s,$$

in which P_s = hour-angle, h = altitude of sun's centre, ϕ = latitude, δ = declination, and dh = sun's semi-diameter. As the hour-angle found from the *Nautical Almanac* is for the end of sunset, it is corrected by subtracting this approximate semi-duration, and the final value in mean time seconds is found by

$$(2) \quad dP = 8 \cos h \, dh / \cos \phi \cos \delta \sin P_s,$$

in which all sines and cosines refer to mid-sunset,

declination and equation of time being constant within $1/10^\circ$ or 1m.

For computing a very good 10-in. slide-rule was used, which gives results as good as the Almanac hour-angles will allow and good enough for rough comparison with observed durations. (In careful study of the effects of atmospheric changes on sunset duration one would compute each sunset separately, with exact hour-angles, formula (2), and four-place logarithms.) In copying, the slide-rule results are rounded off to whole seconds.

In a most unfavourable case, winter solstice and latitude N. 60° , 1921, assuming the data of Table VI., American Nautical Almanac (given on p. 156, 1922), the error of computing may be tested. Computing the hour-angles for the beginning and end of sunset by the sine formula for time sights with declination and equation of time for the moments, and six-place logarithms, they are $42^\circ 15' 16.4''$ and $43^\circ 59' 14.4''$; the local mean times corresponding are 2h. 47m. 37.0s. and 2h. 54m. 33.0s.; the duration of sunset is 6m. 56.0s. = 416.0s.

The mean hour-angle is $43^\circ 7' 15.0''$. Using this in the differential formula (2), four-place logarithms give 415.5+ s., slide-rule 415.0+ s.; so that the differential formula is in error by less than $\frac{1}{2}$ s., or less than $\frac{1}{8}$ per cent.

By slide-rule computing the differential formula with the hour of Table VI., 2h. 54m., the hour-angle at end is $43^\circ 45'$, first approximate semi-duration $51.3'$, final mid-sunset hour-angle $42^\circ 53'+$, final computed duration 417.5s. This is an error of 1.5s. The result for the corresponding date of 1922, given in the table following, 414s., differs on account of a slight difference in the equation of time.

For lower latitudes the error grows smaller, as $\sin P$ approaches 1 and becomes insensitive; e.g. for the same date in 1921 and N. 45° six-place logarithms give 221.5s., four-place 221.7+ s., and slide-rule 221.5s.

For latitudes and dates intermediate among those of the table, and for other longitudes, linear interpolation suffices about as well as it does for the hour of sunset in Table VI., except that the date intervals are much longer; sunrise durations may also be interpolated. While the dates are for 1922, the values given should be good, within their limits of error, in other years as well.

Examination of the table, or of a graph of the same, shows that during the year for any latitude there are two maxima about the solstices and two minima about the equinoxes. The maxima are sharper than the minima. In low latitudes the summer maximum is less than the winter, due to the smaller semi-diameter of the sun; but in high latitudes, beginning above N. 52° , this is reversed, due to the unsymmetrical and exaggerated effect of refraction, which makes the sines of summer solstice hour-angles less than those of the winter solstice. At the autumnal equinox the duration is somewhat less than at the vernal, due to less semi-diameter; this holds good for all latitudes where the term "sunset" has any meaning. Elevation above sea-level would have an effect like refraction.

Since even constant refraction may thus reverse the effects of changing semi-diameter, it is clear that varying refraction must have considerable effect on the duration of sunset. In studying this effect, which led to the construction of the table, it is best to obtain the hour-angle directly with a watch; for when the time-sight formula is used an assumption has to be made about refraction, and an error in this assumption may considerably affect the hour-angle and so the computed duration. Between the tropics this

error is of less account than in higher latitudes, but it is eliminated by the use of a watch.

The Duration of Sunset (in Seconds), 1922.

Lat. N.	0°	10°	20°	30°	35°	40°	45°	50°	52°	54°	56°	58°	60°
Jan. 1	142	144	152	168	180	197	220	253	270	292	319	356	406
" 15	140	142	150	165	177	192	213	243	258	277	300	328	367
Feb. 1	136	138	146	160	170	184	203	226	239	254	271	292	318
" 15	133	135	142	155	164	176	193	214	225	237	251	267	287
Mar. 1	131	133	139	152	160	171	186	205	215	225	237	251	267
" 15	129	131	137	149	157	168	182	201	209	219	231	243	258
April 1	129	131	137	149	158	169	182	202	210	221	232	245	261
" 15	130	132	138	150	159	171	186	207	216	228	241	255	273
May 1	132	134	141	154	164	177	192	217	229	243	258	278	300
" 15	134	136	144	158	169	183	203	230	244	261	281	306	338
June 1	136	139	146	163	174	192	212	244	262	283	309	345	394
" 15	138	140	148	164	178	194	218	252	272	295	327	368	429
July 1	137	140	148	164	176	193	216	251	269	292	322	364	422
" 15	136	138	145	161	173	188	209	242	258	278	304	337	383
Aug. 1	133	136	143	156	168	181	201	227	239	256	275	298	329
" 15	131	133	140	153	162	175	191	214	226	238	254	272	294
Sept. 1	128	131	137	149	158	170	184	204	213	224	237	251	268
" 15	128	130	136	148	156	167	181	199	208	218	229	242	257
Oct. 1	128	131	137	148	157	168	182	200	208	218	229	242	257
" 15	130	132	139	151	159	171	186	205	214	225	237	251	267
Nov. 1	134	136	143	156	164	178	195	217	228	241	256	274	295
" 15	137	139	146	159	171	185	204	230	243	259	277	300	329
Dec. 1	140	143	150	166	177	193	214	245	261	281	305	336	376
" 15	142	144	152	168	181	197	220	254	271	293	322	359	411
Mar. 21	129	131	137	149	157	168	182	200	209	219	230	243	257
June 21	138	140	148	164	177	194	217	253	273	297	328	370	434
Sept. 23	128	130	136	148	156	167	181	199	207	217	229	241	254
Dec. 22	142	145	153	169	181	195	222	255	273	295	324	362	414

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October 23.

Relativity: Particles Starting with the Velocity of Light.

I WISH to point out a peculiar property of the motion of a particle in the theory of relativity when the initial speed is that of light. The result is valid for both the special and the general theory of relativity, but for simplicity I shall consider here only the former case. We start, then, with the Minkowski formula, $ds^2 = c^2 dt^2 - dx^2 - dy^2 - dz^2$. This vanishes for the motion of a light-pulse. The interval ds is imaginary when the velocity is greater than that of light, and is real when the velocity is less than that of light.

If the velocity v of the particle is always equal to c , then all the elementary intervals vanish, so that the length-interval between any two positions is always zero. If, however, the particle merely starts out with the velocity of light and then slows down, so that the acceleration is negative, the interval between the initial world-point P and any other world-point Q will not be zero, and we raise the following question: What is the ratio between the arc PQ and the chord PQ, or, rather, what is the limit of this ratio as Q approaches P? Here, of course, we mean that both arc and chord are measured by means of the interval formula. If we use ordinary Euclidean measurement, of course the limit of this ratio for real curves is always unity. For the Minkowski geometry it turns out that the limit is unity whenever the initial velocity is less than the velocity of light, but in the exceptional case we are now considering we find that the limit is actually different from unity, and, in spite of ordinary intuition, is actually less than unity.

Our precise theorem is as follows:—If the initial velocity is that of light and the initial acceleration is not zero, then the limit of the arc to the chord is $\frac{2}{3}\sqrt{2}$, which is approximately 0.94.

If the initial acceleration is zero, so that the velocity remains that of light for neighbouring points, then the limit may have any value.

That the limit of the arc to the chord is not always unity for curves in the Euclidean plane was first