Three examples have been given by him, all very neat. Writing for shortness the differential equations thus—

Circle, R = 0; *Parabola*, S = 0; *Conic*, T = 0,

he has proved (in Journ. As. Soc. Bengal, vol. lvi. p. 144, and NATURE, vol. xxxviii. p. 173) that in general *in any curve* whatever,

(1) Tan. ∠ of aberrancy = q_1 . R;
(2) Index of aberrancy = q_2 . S;
(3) Radius of curvature of aberrancy curve = q_3 . T;

where q_1, q_2, q_3 are certain functions in general finite. Hence the geometric meaning of the differential equations of the three curves is at once

(1) *Circle.*—Angle of aberrancy = 0
(2) *Parabola.*—Index of aberrancy = 0
(3) *Conic.*—Radius of curvature of aberrancy curve = 0
} right round all curves of each family.

The verbal neatness of these interpretations can hardly be excelled.

A writer (R. B. H.) in NATURE, vol. xxxviii. p. 197, objects to the last that it really only means that *a conic is a conic* (because its aberrancy curve shrinks into the centre)! Now, this is precisely what was to be expected: the differential equation of a curve expresses *exactly* that the curve of some family which osculates it in the highest degree is *the curve itself.* But the new interpretation puts this in a neat form, viz. in assigning a *meaning* to the magnitude F, which differs from zero in general, and whose vanishing at all points of every curve of a certain family (say conic) indicates a property of high generality of those curves.

But the Professor makes, what I conceive to be, the mistaken claim (Proc. As. Soc. Bengal, 1888, p. 75, *et seq.*), that this mode of interpretation is the *only true one;* and further that, accepting this mode of interpretation, *only one meaning* can be attached to it (p. 76, l. 29, *op. cit.*).

Now it must be observed that the equation F = 0 implies *directly*, not only that some one geometric magnitude F vanishes, but also that every geometric magnitude vanishing with F (such as aF, aF^m, *sin*F, &c.) vanishes right round every curve of the family. All of these are equally good geometric interpretations *of the same kind* as proposed.

But the equation F = 0 also implies, more or less directly, countless theorems of position, osculation, &c. All of these may be fairly considered geometric meanings of that equation. Thus, attending to the meaning of "aberrancy," the results quoted involve directly—

(1) *Circle.*—Normal coincides with diameters.

(2) *Parabola.*—Diameters are axes of aberrancy, and meet at infinity.

(3) *Conic.*—Diameters are axes of aberrancy, and are concurrent (in the centre).

Surely these are also *true* geometric interpretations.

Lastly, let the equation F = 0 be multiplied by any of its integrating factors μ, and write for shortness $\int \mu F dx = \phi$. It follows that ϕ = constant. Hence, since the number of integrating factors is infinite, another (indirect) geometric interpretation arises, viz. that all the geometric magnitudes ϕ are constant right round every curve of the family.

These latter *general* modes of interpretation, viz. theorems of position, osculation, and of first integrals ($\phi = c$), I had given eleven years ago (in *Quart. Journ. Math.*, vol. xiv. p. 226).

To the last of these the Professor has objected (p. 76 of his paper quoted), that it is not an interpretation of the equation F = 0 at all, but only of its first integrals $\phi = c$. This is, of course, admitted. But it is worth noting that the connection between the two, F = 0, $\phi = c$, is so very close, that many will accept an interpretation of the latter as a fair (indirect) interpretation of the former also.

In fact, since F = 0 is equivalent to $D_x\phi = 0$, the former is now seen to mean *directly* that there is no variation of any of the magnitudes ϕ right round every curve of the family; and this is a strict *direct* interpretation of the equation F = 0 itself. But many will probably prefer the shorter phrase ϕ = constant, even though it interprets F = 0 only indirectly.

There is, moreover, a *slight* disadvantage in the former mode of interpretation, viz. that the meaning of the magnitude F must necessarily be sought in curves other than, and *usually more complex* than, the curves denoted by F = 0; whereas the interpretation of $\phi = c$ only requires the finding a meaning for ϕ, which is explained in my paper quoted to be any fundamental geometric magnitude *of the curve itself.*

ALLAN CUNNINGHAM, *Lt.-Col., R.E.*

British Earthworms.

THE occurrence of any new animal in England is a point of some interest, however humble that animal may be; and, in order to work out the species of British earthworms, I sent a letter to the *Field* some time back, requesting readers of that journal to forward me specimens. In reply I received a large number of worms from various people, amongst them being Mr. F. O. Pickard Cambridge, of Hyde, who has very kindly sent me several parcels of worms. One of these parcels contained some very fine gravel taken from the bed of a stream, together with a number of small worms about 1½ to 2 inches in length. These turned out to be a species of *Allurus*, a genus formed by Eisen for a worm in which the male pores are on the thirteenth segment instead of on the fifteenth, as in the other genera of the family Lumbricidæ. Only one species is at present known, viz. *A. tetraëdrus;* it is of a beautiful sienna colour, with a dull orange clitellum.

I wish to record, for the first time, its occurrence in England, and also to draw attention to the fact that it lives below water, at any rate for some part of the year. Mr. Cambridge has been most obliging in giving me the facts as to the place in which he found the worms: they occur in the gravelly bed of a stream which at certain times of the year runs down so low as to leave small gravelly islands 2 or 3 inches high. In these islands he found *Allurus;* but he finds none in the banks of the stream. We already know of *Criodrilus* as being a thoroughly aquatic earthworm, living in the muddy beds of rivers and lakes; and although this worm has not yet been recorded in Great Britain, I see no reason to doubt that it exists here.

I should add that Mr. Beddard has informed me that he received a specimen of *Allurus* from Lea, Kent, some time after I received these from Hyde. It has been recorded also from Sweden, Italy, and Tenerife.

WM. B. BENHAM.

University College.

THE SUN MOTOR.

INDIA, South America, and other countries interested in the employment of sun power for mechanical purposes, have watched with great attention the result of recent experiments in France, conducted by M. Tellier, whose plan of actuating motive engines by the *direct* application of solar heat has been supposed to be more advantageous than the plan adopted by the writer of increasing the intensity of the solar rays by a series of reflecting mirrors. The published statements that "the heat-absorbing surface" of the French apparatus presents an area of 215 square feet to the action of the sun's rays, and that "the work done has been only 43,360 foot-pounds per hour," furnish data proving that Tellier's invention possesses no practical value.

The results of protracted experiments with my sun motors, provided with reflecting mirrors as stated, have established the fact that a surface of 100 square feet presented at right angles to the sun, at noon, in the latitude of New York, during summer, develops a mechanical energy reaching 1,850,000 foot-pounds per hour. The advocates of the French system of dispensing with the "cumbrous mirrors" will do well to compare the said amount with the insignificant mechanical energy represented by 43,360 foot-pounds per hour developed by 215 square feet of surface exposed to the sun by Tellier, during his experiments in Paris referred to.

The following brief description will give a clear idea of the nature and arrangement of the reflecting mirrors adopted by the writer for increasing the intensity of the solar heat which imparts expansive force to the medium propelling the working piston of the motive engine. Fig. 1 represents a perspective view of a cylindrical heater, and a frame supporting a series of reflecting mirrors composed of narrow strips of window-glass coated with silver on the under side. The frame consists of a light structure of wrought iron or steel, provided with transverse ribs as shown by the illustration, each rib being accurately bent to a parabolic curvature whose focus coincides with the axis of the cylindrical heater. It needs hardly be stated that the mirrors supported by the said transverse ribs continue from side to side of the frame, which accordingly resembles a parabolic trough whose bottom is composed of mirrors. It will be readily understood that this trough with its bent ribs and flat mirrors forms a perfect parabolic reflector, to which a cylindrical heater, as stated, may be attached for generating steam or expanding the gases intended to actuate the piston of the motive engine. Regarding the mechanism for turning the reflector towards the sun, engineers are aware that various combinations based on the principle of the "universal joint" may be employed.

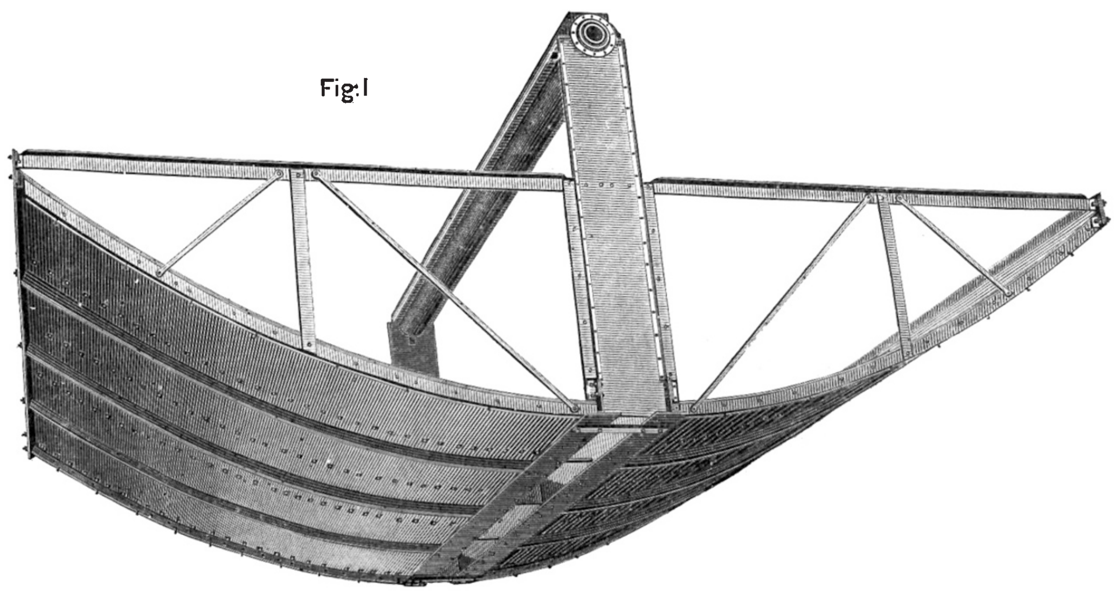
Concerning previous attempts made in France to utilize solar energy for mechanical purposes, it is well known that practical engineers, having critically examined Mouchot's solar engine, which M. Tellier proposes to supersede, find that it is incapable of developing sufficient power for any domestic purpose. Again, the investigations carried out by order of the French Government to ascertain the merits of Mouchot's invention show that irrespective of the great expense of silver-lined curved metallic reflectors for increasing the insufficient energy of direct solar radiation, these reflectors cannot be made on a sufficient scale for motors having adequate power to meet the demands of commerce; nor is it possible to overcome the difficulty of rapid wear of the delicate silver lining of the metallic reflectors consequent on atmospheric influence, which after a few hours of exposure renders their surfaces tarnished and ineffective unless continually polished. A glance at the accompanying illustration (Fig. 1) shows that the reflector constructed for my sun motor differs altogether from that originated by Mouchot, which Tellier's apparatus, tested at Paris, was intended to displace.

Description of the Illustrated Reflector.

(1) The mirrors which reflect the solar rays are devoid of curvature, being flat narrow strips of ordinary window-glass, cut to uniform width and length, perfectly straight.

(2) The under sides of said strips are coated with silver by a process which prevents the action of the sun's rays from destroying the silver coating as in ordinary looking-glasses.

Fig. 1



(3) The mirrors supported by the bent metallic ribs extending from side to side of the parabolic trough, are held down by the heads of small screws tapped into the ribs. Thin slats of wood may be introduced between the mirrors and the ribs—an expedient of some importance in localities where the reflector is exposed to high winds.

(4) It needs no explanation that the *reflecting surface* of the mirrors cannot become tarnished by atmospheric influence, since the bright side of the silver coating is permanently protected by the glass; hence it will be only necessary to remove *dust* from the mirrors, an operation readily performed by feather brushes secured to light handles of suitable length.

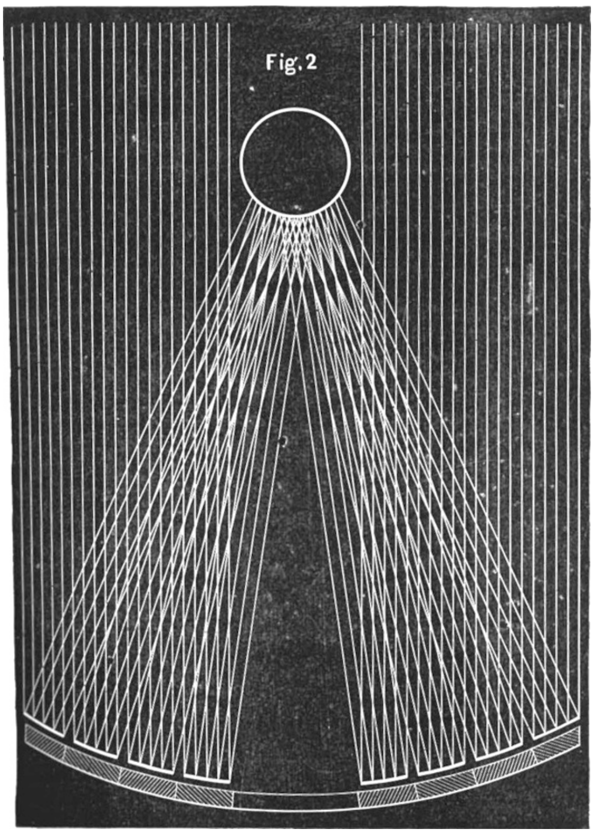
(5) The frame of the reflector, being composed of rolled bars of iron or steel, requires no finish, excepting the top of the transverse ribs, which must correspond accurately with a given parabolic curvature. It should be observed that the needed accuracy is readily attained by a cutting tool guided by a bar of proper form.

(6) Regarding cost of construction, it will suffice to state that manufacturers of glass, both in the United States and Germany, supply the mirrors, cut to exact size and silvered, at a rate of 60 cents. per square foot, the weight being 106 pounds per 100 square feet. Consequently the cost of the reflector and heater for the sun motor will not much exceed that of a steam boiler and appurtenances, including chimney. The cost of the engine apart from the reflector, will not be greater than that of an ordinary steam-engine.

(7) With reference to durability, it will be evident that the light metallic frame with its mirrors, and a heater acted upon only by reflected solar heat, will last much longer than steam boilers subjected to the action of fire, soot, and corrosion.

Let us now briefly consider the distinguishing feature of the sun motor—namely, the increase of the intensity of the sun's radiant energy by *parallel* rays and *flat* reflecting surfaces permanently protected against atmospheric influence. It has been supposed that the lens and the curved reflecting surface, by converging the sun's rays, could alone increase the intensity of radiant heat. But Newton's demonstration, showing that the temperature produced by solar radiation is "as the density of the rays," taught me to adopt in place of curved surfaces and converging rays, flat surfaces and parallel rays, as shown by Fig. 2, which represents a transverse section of part of the reflector. The direct vertical solar rays, it will be seen, act on the mirrors; while the reflected rays, divided into diagonal clusters of parallel rays, act on the heater, the surface of which will thus be exposed to a dense mass of reflected rays, and consequently raised to a temperature exceeding 600° F. at noon during ordinary sunshine.

The cost, durability, and mechanical energy of the sun motor being thus disposed of, it remains to be shown whether the developed energy is continuous, or whether the power of the engine changes with the increase and diminution of zenith distance and consequent variation of atmospheric absorption. Evidently an accurate knowedge of the diathermancy of the terrestrial atmosphere



is indispensable to determine whether the variation of the radiant energy is so great that the development of constant power becomes impracticable. Of course, manufacture and commerce demand a motor developing *full power* during a modern working day of *eight* hours. Observations relating to atmospheric diathermancy continued during a series of years, enable me to assert that the augmentation of solar intensity during the middle of the day is so moderate that by adopting the simple expedient of wasting a certain amount of the superabundant heat generated while the sun is near the meridian (as the steam engineer relieves the excess of pressure by opening the safety-valve) a uniform working power will be developed during the stipulated eight hours. The opening of the safety-valve, however, means waste of coal raised from a great depth at great cost, and possibly transported a long distance, while the radiant heat wasted automatically by the sun motor is produced by fuel obtained from an inexhaustible storehouse free of cost and transportation.

It will be proper to mention that the successful trial of the sun motor described and illustrated in NATURE, vol. xxxi. p. 217, attracted the special attention of landowners on the Pacific coast then in search of power for actuating the machinery needed for irrigating their sun-burnt lands. But the mechanical detail connected with the concentration at a single point of the power developed by a series of reflectors was not perfected at the time; nor was the investigation relating to atmospheric diathermancy sufficiently advanced to determine with precision the retardation of the radiant heat caused by increased zenith distance. Consequently no contracts for building sun motors could then be entered into, a circumstance which greatly discouraged the enterprising Californian agriculturists prepared to carry out forthwith an extensive system of irrigation. In the meantime a simple method of concentrating the power of many reflectors at a given point has been perfected, while the retardation of solar energy caused by increased zenith distance has been accurately determined, and found to be so inconsiderable that it does not interfere with the development of constant solar power during the eight hours called for.

The new motor being thus perfected, and first-class manufacturing establishments ready to manufacture such machines, owners of the sun-burnt lands on the Pacific coast may now with propriety reconsider their grand scheme of irrigation by means of sun power.

JOHN ERICSSON.

THE WHITE RACE OF PALESTINE.

ON the occasion of my first visit to Palestine I was struck by the number of blue-eyed, fair-haired children whom I met with in the towns and villages, more especially in the mountainous parts of the country. At the time I supposed them to be the descendants of the Crusaders or of the other natives of Northern Europe who found their way to the Holy Land during the Middle Ages. But a new light has recently been thrown on the matter by the ethnological observations made by Mr. Flinders Petrie in Egypt.

The winter before last Mr. Petrie was commissioned by the British Association to take casts and photographs of the ethnological types represented on the Egyptian monuments, and to note, wherever it was possible, the colour of the skin, eyes, and hair. It was not the first time, however, that notes of the kind had been taken. Some years ago, Osburn, a careful observer, had noticed that in the sculptures of Ramses II. at Abu-Simbel "the Shasu of Kanana" were depicted with blue eyes, and red hair, eyebrows, and beard, and the Amaur with "the eyes blue, the eyebrows and beard red." As "the Shasu of Kanana" lived a little to the south of Hebron, while the Amaur are the Amorites of the Old Testament, it was clear that a population existed in Palestine in the fourteenth century before our era which had all the characteristics of the white race.

Mr. Petrie's observations have abundantly verified this conclusion. He finds that, on the walls of a Theban tomb, the chief of Kadesh on the Orontes is painted with a white skin, and light red-brown hair. Kadesh was the southern capital of the Hittites, after their invasion of Syria, but the Egyptian inscriptions describe it as being "in the land of Amaur"; and that its chief must have been an Amorite is shown by the fact that the Hittites are depicted with yellow or orange skins, their hair being black, and their eyes dark.

The physiognomy of the Hittites and Amorites, moreover, differed widely. The Egyptian artists agree with the native Hittite monuments in representing the former