Measurement by photography

10 words a line } 140
14 lines } × 18
18 pages 1120
140
2520 words

Note to printer

the letters underlined with red are to be printed as romans, not italics. The italics are faintly underlined with the pen.

Record

Measurement by photography

F.2 1

From Francis Galton
42 Rutland Gate SW

2 cards containing in all 5 figs accompany this

The art of making perspective drawings of solid objects is well known; in this paper I propose to direct attention to the converse art of deducing the measures of solid objects from their perspective representations in photographs.

The extraordinary power now possessed, through the accuracy of lenses and the rapidity of films, of ~~seizing~~ permanently recording every detail in the momentary positions of a multitude of objects, opens a wide field for the methods about to be explained. I was led to think about it owing to the difficulty of obtaining direct measures of ~~a considerable number of~~ ~~numerous~~ thorough bred horses, as data for studying heredity. ~~of hereditary value~~. It was dangerous as well as difficult to ~~take~~ measure them; thoroughbreds being extremely sensitive and often vicious, and very sudden & ~~swift~~ far-reaching in their various offensive movements.

Two processes will be described; the first is of general application ~~and~~ but requires the use of two cameras, working simultaneously if the objects are in motion; the other, ~~and~~ requires only one camera, and is applicable to a limited but still considerable number of cases, ~~and~~ and many ~~valuable~~ useful measures of animals ~~may be obtained~~ being obtainable by it. In both processes the camera ~~is~~ must be a fixture, at such a distance from the place to which the animal is to be ~~set~~ stand that no probable error in its position will sensibly affect the focus or ~~take it~~ throw its image out of the field of view. Lastly, certain fiducial marks have to be made on the ground; they may be so small as to to appear as mere dots in the photograph & ~~could~~ might be chipped on bricks or paving stones let flush into the ground, and afterwards painted.

The ground, or ~~[illegible]~~ plot, on which the animal is to be photographed, is supposed to be hard and level, and, when two cameras are used, to contain 6 fiducial marks whose relative positions have been carefully measured and mapped; they appear in the ground plan, fig 3, as a, b, c, d, M_1, M_2.

The optical centres of the two cameras N_1, N_2, are vertically above M_1, M_2 & their heights above the ground, M_1N_1, M_2N_2, are known. This completes the necessary installation, though two supplementary marks ~~would be~~ are convenient, the one placed on the opposite side of a from b and at an equal distance from it; the other similarly on the opposite side of c from d.

The ground plan is drawn true to the scale that is shown by the graduations & sectional lines, ~~[illegible]~~, and ~~that scale should~~ it ought to be of fair size to admit of easy manipulation, large enough to ~~not be too small, if the ground plan~~ cover an ordinary drawing board. ~~the size would be very suitable for the processes to be described.~~ The side view, fig 4, is on the same scale as the ground plan.

The broken lines in Fig 3 & 4 represent moveable threads each of which has a loop at one end to slip over a pin; when it has been stretched in any given direction, the other end can be maintained in position by laying a small weight upon it. One of these threads slips over M_1 in fig 3 and another over M_2; two threads are slipped over the same pin N_1 in fig 4. The dotted line TS merely indicates the direction to be followed by the eye in the particular case ~~here~~ referred to here.

P is an isolated spot in space, in view of both cameras. It does not appear in fig 3, ~~because when it stands vertically above~~ but Q ~~which~~ indicates the point in the plot that lies vertically beneath it. Neither does it appear in Fig 4 because there stands laterally behind T, while Q stands laterally behind S, but it is seen in ~~fig~~ the general view given in Fig 5. In the ground plan fig 3, a is the centre from which the 3 coordinates to P, ~~[illegible]~~, namely $\underline{x}$, $\underline{y}$, and $\underline{z}$,, are to be plotted, x and y lying in the plane of ~~area~~ the plot, and x coinciding ~~with~~ in direction with a line passing through $\underline{a}\,\underline{b}$. Thus in fig 3, x and y are respectively equal to $\underline{ak} = SQ$ and to $\underline{k}Q = \underline{a}S$. $\underline{z}$ is perpendicular to the ground and is ~~identical~~ equal (for the reasons already given) ~~given, as~~ to ST in fig 4. The two photographs are shown in figs 1 & 2, the first being taken by the camera N_1, the other by the camera N_2. ~~The scale of these photographs may, if desired, be determined by the lengths of ab, cd, but it is immaterial to us now.~~ Each photograph ~~shows~~ contains a perspective picture of P, and of two out of the six fiducial points (or of three points if there be eight of them in all); these are distinguished in fig 1 as $\underline{p_1}$, $\underline{a}$, $\underline{b}$; in fig 2 as $\underline{p_2}$, $\underline{c}$, $\underline{d}$. The ~~dotted~~ lines do not appear in the photograph; they are lines of operation, ~~the~~ best plotted on the back of the print, guided by prick holes made with a fine needle through the above mentioned points. The line $p_1 g$ is drawn perpendicularly to ab produced, and $p_2 f$ to cd produced. ~~The scale of these photographs may, if desired, be determined by the lengths of ab, cd, but it is immaterial to the now present purpose of determining lengths in the plan from lens~~

First process – ~~If determined by~~ The way in which the coordinates of P are to be plotted will now be described; the rationale of it will follow. The first object is to lay down g and f on the ground plan (fig 3), such that

$$ag = ab \times \frac{ag}{ab} \quad \text{and} \quad cf = \cancel{cf \times \frac{cf}{cd}} \; cd \times \frac{cf}{cd},$$

(regard being paid throughout to signs). ag, ab, cf and cd are measured on the photographs by any convenient scale; and the value of the fraction are obtained by division, or more quickly by Crelle's tables or else by a sliding rule. g and f being plotted on fig 3, the intersection of the threads stretched from M_1 M_2 through them respectively, fixes the position of Q; ~~and the~~ they the corresponding values of x and y are read off at once by means of the sectional lines; they are $ak = SQ = x$ and $kQ = aS = y$. This value of y is ~~then~~ utilised in fig 4 to determine S, aS being taken equal to y. Also ~~at~~ t is laid down in the same figure on the perpendicular ~~at~~ to $M_1 a S$ (at a_1) such that $at = ab \times \frac{at}{ab}$, ~~and the~~ then two threads are stretched from N_1, the one passing through S & the other through t. The intersection of the latter with the vertical at S ~~gives~~ determines T, and the value of $ST = z$ is read off by means of the sectional lines.

Thus the values of the three coordinates of P are obtained with facility.

Next suppose a second point U whose coordinates have been determined in the same way, and that it is desired to learn the distance between P and U:— (1) in the plane of xy, (2) in that of xz, (3) in that of yz; also (4) the direct distance between them. ~~Call~~ Let l, m, n, be the distances respectively between the two values of x, of y, and of z; then

$(1) = \sqrt{(l^2+m^2)}$; $(2) = \sqrt{(l^2+n^2)}$; $(3) = \sqrt{(m^2+n^2)}$; $(4) = \sqrt{\{l^2+m^2+n^2\}}$

which may either be calculated by the help of Barlow's tables of Squares, &c, or be plotted as right angled triangles. The rationale of this is too simple to require detailed explanation.

What has next to be said, regards the rationale of the ~~original~~ process of finding the coordinates. Fig 5 is a general view in perspective of the installation and ~~[illegible]~~ shows the optical lines; it includes more than has already been shown in figs 3 & 4. atpg is part of what is technically spoken of ~~known~~ (as the "picture-plane") in books about perspective.

It is a vertical plane squarely interposed between N_1 the "point of sight" (or camera) ~~the eye (or camera)~~ and the object; the intersection with this plane of lines proceeding from all points of the object, to N_1, produces the perspective picture of the object, (drawn as it were on the picture plane, as both picture-plane and object are seen from N_1.

The photograph taken in a camera, whose back is parallel to the picture-plane, is merely a reduction of the ~~[illegible]~~ picture on that plane; its internal proportions are ~~the same~~ identical and the distance between any two given points on the photograph, ~~any measure on it which we call X, may~~

say = $\underline{r}$, may be reduced to that between the two corresponding points on the picture plane = **r** (roman r) by means of the ratio **r** (roman r) : $\underline{r}$ :: ab : $\underline{ab}$.
So the photograph may be ignored in ~~the explanation, which~~ explaining ~~mainly deals with~~ primarily the relation between the perspective upon the picture-plane and the object. ~~Allusion should~~ here ~~be made~~ ~~to~~ The letters employed in the diagrams, ~~which~~ are of three sorts, Capitals, roman, & italics; the former are used for the object, the second for the picture-plane, the third for the photograph. The line bagk where the picture-plane intersects the ground, belongs to both of them, but is taken for ~~greater~~ convenience as part of the picture plane; that line is the "base" or "fundamental" line of writers on perspective.

The data in fig 5 are a, b, the line through them, and M, a S perpendicular to that line; there ~~are~~ being

~~there~~ due to the installation; also p ~~[illegible]~~ derived from (p, in fig 1) the Photograph; all the rest of fig 5 is derivative. Thus $N_1 p$ produced, passes through P, and a vertical plane through ($N_1 p P$) ~~that line~~, passes through M_1 Q, intersecting the picture-plane and the ground at g. Consequently pg is perpendicular to ~~[illegible]~~ bag (~~and with the~~ in the same way pg is perpendicular to ~~a~~ ba in the photograph), also the line from M_1 through g will pass through Q. This ~~is the~~ property of g ~~that~~ was utilised, as will be recollected, for finding Q, by two threads stretched respectively from M_1 through g, and from M_2 through f. The position of P lies at the intersection of $N_1 p$ produced, with the perpendicular from Q, but it cannot so be plotted either in fig 3 or 4. For this reason ~~the~~ various parallels have been drawn in fig 5, whereby

(see also fig 4)
$aS_\lambda = kQ = y$ and $ST = QP = z$. There is yet another result from fig 5, which had better be mentioned and done with now, although not required until we reach the second process; it is that aS = $\underline{g}q$ = the projection of the horizontal distance y upon the vertical picture-plane.

The reader may well be puzzled by the numerous lines and planes in fig 5; if so, he should make a small and rough model, say (as I did) by driving the ends of two long nails into a piece of wood, to represent the verticals at S and Q, and a shorter nail at M_1, connecting them with thread, using say, a comb between whose teeth the threads pass, to do duty as a picture-plane, and imagining the rest. This small amount of help given to the eye, clears the ideas at once, for by far the greater part of the difficulty in problems in solid geometry in books is due, not to their inherent complexity, but to ~~the impossible attempt to represent them clearly by diagrams~~ their imperfect representation by diagrams.

Second process.) ~~In that which has been described~~

(The only use of the second camera was to determine Q, but a considerable class of cases exist in which Q is given by the photograph, simultaneously with P; or, if not given ~~directly~~, in which the ~~its~~ position of Q may be inferred. If P is the top of a vertical column, ~~post in the ground~~, Q is the base of the ~~post~~ column & so on. If P be the withers of a standing horse, the position of Q may be found very closely by bisecting ~~the~~ the interval between any two symmetrically disposed points on the photograph of his fore hoofs, and similarly as regards his ~~the~~ hind ones, joining the points of bisection $j_1 j_2$, (Fig 6) & dropping a perpendicular from p, cutting the line ~~till it meets that~~ $j_1 j_2$. The fore feet of a standing horse are rarely more than one hoof's breadth (4 or 5 inches) wider apart & similarly as regards the hind feet, consequently a plane passing through the ridge of ~~the~~ his back and through $j_1 j_2$, is vertical or very nearly so to the ground, hence ~~each~~ perpendiculars drawn to $j_1 j_2$ from any point P whether along the back or along the belly, give the corresponding Q. Thus the height of the withers, that of the rump, and the vertical depths of the chest & belly are all measurable by the process about to be described. Fig 6 ~~represents~~ shows the data that are now available, viz a, b, p_3 and q_3, whence ~~$gq = as$ (fig 4)~~ as (fig 4, 5) $= gq$ fig 5, $= ab \times \frac{gq}{ab}$, which determines the position of S in fig 4. Now stretch a thread from N_1 through S_1

its intersection with $M_1 a$ produced, determines S; then ~~and~~ as ~~consequently~~ $aS = y$, the value of y ~~which~~ is read off at once; ~~as well as~~ and that of $ST = z$, as before. ~~Then~~

Turning to fig 3, we know that Q lies in ~~the same~~ a horizontal line drawn through S, therefore its precise position is ascertained by the intersection of the stretched thread from M_1, through g; with that line; ~~then~~ in this way $x = QS$ is found.

It will be observed that the length $M_1 N_1$ must be a considerable fraction of $M_1 S$ in order to determine y with fair precision. ~~in that way~~. The proportions of an installation that worked well under all conditions were ~~are~~ Equivalent focus ~~of the~~ ~~portrait of lens~~ of portrait lens 2.76 inches, aperture 1.1 inch, angular width of field of view more than ~~over~~ 40°, $M_1 a = 200$ inches, $N_1 M_1 = 60$ inches. Here the length $M_1 a$ being ~~more than 70~~ 72 times the length of the Equivalent focus of the lens, all objects beyond **a** were sensibly within focus, ~~&~~ the scale of reduction of the photograph ~~was~~ being as 1 to 72 . when the object was at **a**, and smaller still when ~~it is~~ further. (Small as this scale is, it easily admits of measurements being made without using a lens, to the nearest inch.) The camera ~~was~~ had to be a little tilted, to bring **ab** into a convenient position in the field; the focussing screen ~~being~~ was of course equally tilted backwards, so as to remain vertical and parallel to the picture-plane. ~~With~~ If a lens of longer focus were used, M, N, would have to be proportionately higher, and the view of (say) the horse would not be a fair broadside one . The distance assigned above to M, **a** is ~~found~~ shown to be unnecessarily great ~~for~~ when the second process ~~any~~ is the employed, for some of the beautiful photographs that are now procurable of race horses, ~~of which the s~~ whose scale is about 1 in 25, would have been easily measurable, had fiducial points existed, indeed I may say that nearly all I have seen would be suitable had the ground been hard enough to show their hoofs clearly, instead of being turf or covered with litter. As a rule, the ground is rarely too much foreshortened, and amply enough of it is in sharp focus.

The surest scientific basis for forming theories and testing current beliefs in respect to the probabilities of heredity, ~~tis~~ is supplied by records of measurable dimensions, that is by quantitative in distinction to qualitative facts. Considering the importance to practical breeders that ample collections of such records should be obtain for competent students to analyse & discuss the following proposal is not unreasonable. Namely that in connection with every exhibition of pedigree stock, the authorities should establish a photographic installation consisting of at least one fixed camera and fiducial points by which all the prize animals should be photographed as a matter of course and where other exhibitors might at a small cost have their own animals photographed so far as time permitted. The important difference between the proposed photographs & those now obtained, and which they would supplement and not supersede, would lie in their showing 2 or 3 minute fiducial marks. They would be on a small scale, taken by snap shots and not necessarily artistic, but they would be strictly measurable, whereas those taken at present are not.

Very much might be added, ~~to what has now~~ regarding ~~other~~ extensions of the two processes, and ~~many~~

much that has been cursorarily dealt with might have been expanded and several side issues followed out, but by doing so the paper would have become unreasonably long.

Francis Galton

f. 20b

f. 20c

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f. 1av

Horse

say 60 inches high at withers

$1\frac{1}{2}$ inch in a small photo

that gives scale of

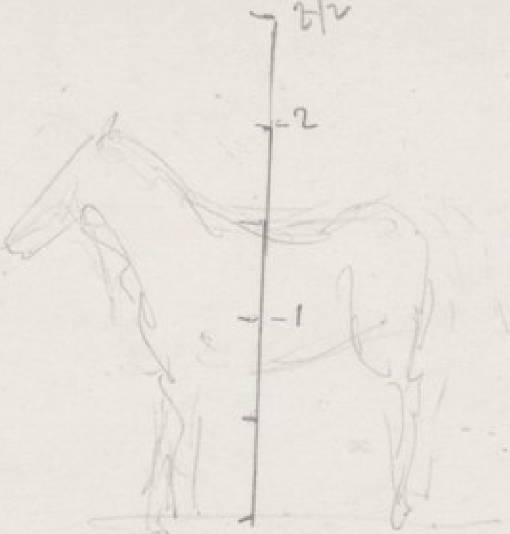
$\frac{1}{40}$ inch in photo = 1 inch in reality

$\frac{1}{2}$ inch

20^{th} of inch scale = 2 inch in real

the dots are 40^{th} of 1 inch   0   10 inch

Could work to ½ inches without lens



2 inches high in a medium sized photo

1 inch in horse = $\frac{1}{30}$ inch in photo or a little less than 1 mm   (25^{mm} = 1 inch)

a horse about 16 hands high represented in a photo as 2½ inches high is on a scale of (1 millimetre to 1 inch)

2½ inches high is a largish scale, like those I bought in the Strand

$2.5 \times 2 = 60$ $x = 24$

$20 \times x = 60$

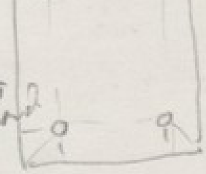
3 inches high is large = $\frac{1}{20}$th inch scale

Pricking photos

Criss cross screen frame outside the 0 corners of plot

Covers of white crockery ointment pots. The 3 pots are $1\frac{1}{2}$ inches diameter outside, $1\frac{1}{4}$ " " inside

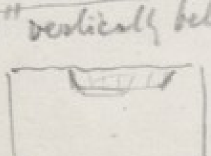
Wooden tent pegs, iron bound.



With my usual rectilinear & small camera

A square of 10" inches in side, whose nearest edge is 36" from object glass & 11" vertically below

it appears thus (inverted) on ground glass screen & would do



the grass of plot are very sharp

It is better lengthways, but with small plot

One wants a wider angled lens though.

this would do

Tilting the camera & keeping the screen vertical the result is admirable at 26 inch from nearest edge of square the plot fills the lower part of the screen & leaves room for the horse  (plate long side horizontal)

No 30th height of camera × 4·5 = distance to mid board does well

$b = 12 \times 1\frac{1}{2}$ inches $= 18$ inches

$a = 2.5 l$ $a = 2.5 \times l = 30 \times 1\frac{1}{2}$ in $= \underline{45 \text{ inches} = a}$

$\frac{l}{s'} = 4$ $c =$

$\frac{l}{s'} = 4$ $r = 0.87 \times 18 =$

$$\begin{array}{r} 87 \\ \hline 126 \\ 144 \\ \hline 156.6 \end{array}$$

present height 14.00

add 1.66

$$\begin{array}{r} 18 \\ 2.5 \\ \hline 90 \\ 36 \\ \hline 450 \end{array} \qquad \begin{array}{r} 18 \\ 0.87 \\ \hline 126 \\ 144 \\ \hline .66 \end{array}$$

which it will be seen that an allowance of ~~(~~ 60 inches =5 feet (call it d) ~~will com~~ between the greatest and least distance from the camera of any point on the visible side of the horse, is sufficient. The problem is to find OP (call it $\underline{a}$) such that when the camera is sharply focussed on P it will have ~~with~~ a back focus which we will call $\underline{b}$ and again when it is sharply focussed on Q, it will have a back focus equal to $b - r$, ~~the difference between the its two back foci shall and be equal to~~ $\underline{r}$ which may be taken at 5 inches

Let f = Equivalent focus of lens, ~~then b = back focal length for P~~

$$(1) \quad \frac{1}{f} = \frac{1}{a} + \frac{1}{b}$$

$$(2) \quad \frac{1}{f} = \frac{1}{a+d} + \frac{1}{b-r}$$

~~Eliminating b~~ whence $\bar{b}$ being eliminated we get

$$a = \sqrt{\left\{ \frac{df^2}{r} + \frac{1}{4}(2f-d)^2 + df - f^2 \right\}} - \frac{1}{2}d + f$$

$\begin{array}{r} 387.00 \\ -25 \\ \hline 362 \end{array}$

or, neglecting terms that are relatively unimportant, & giving r the value of 0.01,

$a = 10 f \sqrt{d} - \frac{1}{2}d + f$ that is $a = 50 \times 7.74 - 30 + 5 = 362$ inches; = 30 feet 2 inches.

· call it 360 = 30 feet

Taking the height of the withers of the horse at (= 5 feet = 60 inches, it is usually more), the ~~corresponding~~ ~~here of~~ height in the image on the negative in the camera will be $\frac{5 \times 60}{360}$ inches $= \frac{5}{6}$ths of an inch, which if ~~multip~~ enlarged 3 times becomes 2.5 inch, as proposed. ~~The~~

The reduction of scale is $\frac{5}{360}$ = ~~about 1.4 in a 100 or~~

or $\frac{1}{50}$ $= \frac{1}{52}$ say, about one fiftieth.

2) Size of plot and its distance from camera.

The focal distance of every visible part of every animal in the plot must be the same, within some accepted small limit of deviation, which we will call r, and estimate provisionally at one hundredth of an inch, for greater refinement than this is hardly practicable. For measurement of horses a plot of 144 inches (=12 feet) in length × ~~84 inches (=7 feet)~~ 48 ~~60~~ inches (= 4 feet) in width is sufficient & allow ~~for the~~. The extreme height of the horse standing on the plot being 7 feet. ~~A reference~~

* The figures shew the extreme positions of the nearer side of a horse ~~forwards or backwards~~ ~~from~~ the camera whether further or nearer to else ~~in front or behind~~ to one side or the other of its axis, from or to ~~the right or left of the median line~~

side

Man d R a M

This necessitates a considerable height for the camera,
If the plot be 30 feet distant from its base then
the camera must be 6 feet above the ground, the apparent width
of the plot as seen from the camera will be equal to that of a vertical board of 12 inches
in ~~[illegible]~~ width set on edge along the nearer side of the plot; ~~and~~ the
picture of it on the negative will be $\cancel{\frac{12}{50}}$ $\frac{12}{52}$ and that on the
enlarged position will be ~~$\frac{360}{[illegible]}$ or 1.2 inches [illegible]~~ $\frac{12 \times \cancel{[illegible]} 3}{52}$
or ~~[illegible] one inch~~ ~~or 1.2 inch~~ = $\frac{36}{52}$ ~~[illegible] or about 3/4 [illegible]~~

52/360(0.692 = 0.692 or 0.7 inch nearly.
~~[illegible]~~
[illegible]
312
480
468
120

Height of camera above ground.

It is necessary to have a fair view of the plot in the photograph in order to determine the position of objects on it & more especially the ~~point~~ place where the vertical from each point of the animal touches the ground. After several trials it seems that a foreshortening to the extent of ~~to~~ $\frac{1}{5}^{th}$ of the natural size is the most that can be permitted. ~~On~~ ~~is possible~~ the other hand a foreshortening to the extent of only 1 in 4 is rather more than is suitable for the good performance of bases. The camera has to be tilted considerably even for ~~the~~ 1 in 5, its back ~~but not too much for the back of it must~~ being ~~to~~ ~~forced~~ strictly in a vertical plane.

f. 1r 6

Feasible accuracy

The precision with which a fairly sharp photograph can be measured, is surprising. The best way & one which I have largely used in other investigations is just to prick through the photograph with just the point ~~only~~, of a very fine needle The hole is clearly seen on the back as an excellently defined point, suitable for ~~very~~ accurate measurement. Even if the photograph be slightly blurred the judgment of the eye ~~can~~ may be trusted to prick truly in the middle of the blur. I see no difficulty whatever in measuring to one hundredth of an inch ($\frac{1}{4}$ millimetre)

f. 1i 7

The ~~magnitudes to be dealt with are~~ kind of accuracy required in these measurements is to be found as follows.

The height of a horse at his withers may be taken at 60 inches and the greatest exactness in measurement that is worth attempting, is not to exceed an error of ~~1/8~~ $\frac{1}{4}$ inch, or ~~1/8~~ $\frac{1}{240}$th of his height.

Now the distance from the camera of a point half way across the plot, is 360 + 24 or 384 inches, so one inch of ~~error~~ difference in ~~the~~ horizontal position of the horse before or behind that point ~~on either side~~ would make ~~an error~~ a difference of $\frac{1}{384}$ in ~~the~~ his computed height, and this relation may be taken ~~as the approximate average error effect~~ to prevail approximately throughout the plot. It follows by rule of three that 1.6 inch of error in his actual horizontal position would make ~~1/240~~ the allowable $\frac{1}{240}$ difference in ~~the~~ his computed height ~~of the withers~~. ~~and that is $\frac{0.7}{1.8}$ = .044~~ There are

$\frac{48}{22.8}$ = 28.9 such ~~points~~ intervals in the ~~48 inches of the~~ actual plot and each of them is on the average $\frac{70}{28.9}$ = ~~...~~ 0.0242 in the perspective in the photo, that is $\frac{1}{41.3}$ too much.

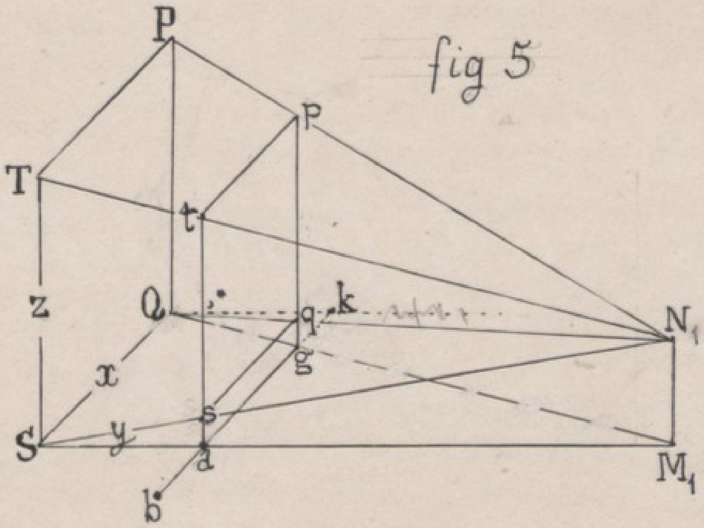
Now 1.66 inch of actual horizontal measure corresponds to 0.0242 inch on the enlarged photo print that is to about $\frac{1}{40}$ inch, which is quite a large quantity when dealing with moderately careful measures of delicate pricks.

So there is no difficulty in fulfilling the ~~sense of~~ requirements of reasonable accuracy

real 1.66 : 48 :: x : 0.7 red: persp

x = 48/1.162 (0.0242

fig 5



f. 11r

(2

F. Galton

'Measurement by photography'

42 Rutland Gate SW

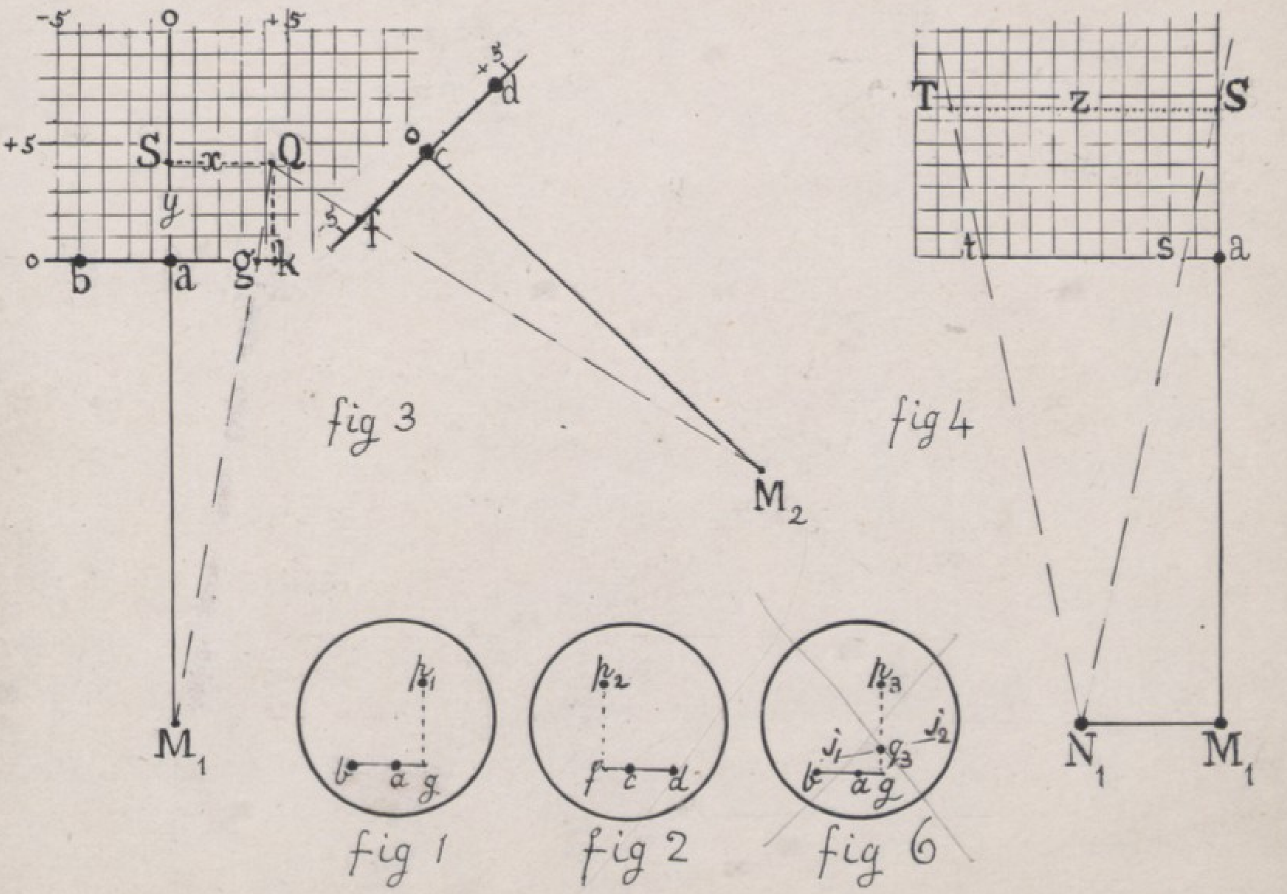


fig 3
fig 4
fig 1
fig 2
fig 6

f. 1kr

1

F. Galton

'Measurement by photographs'

42 Rutland Gate

SW

f. 25 1

Few persons seem to have an adequate idea of the vast care and cost that is bestowed in this country alone, upon pedigree stock. ~~Many~~ Stud books are kept of many varieties of horses, cattle, dogs and other domestic animals ~~have their several stud books~~. More than 000 foals are bred yearly from race horses whose genealogy is known for 10 or 20 generations; there are about the same number of "hackneys" ~~of~~ whose stocks ~~that go~~ are all traced back for more than a century. "Shire" cart horses and even Shetland ponies swell the list, while the other domestic animals add to it almost as numerously. Yet notwithstanding that the object of all this painstaking is to secure

f. 2v

plural cantality

good breeds, there exists no adequate record of the experiences gained. The stud books are silent as to those definite facts which are the first that a scientific inquirer into heredity desires to ascertain, ~~the primary ones among these being measurements~~.

The problem that these unrecorded facts would enable us to solve, is that of the statistical influence of heredity, such for example as would answer this question "among the produce of ~~a~~ many horses of such and such a breed, whose depth of chest is so many inches, (1) what will be the average depth of chest? (2) what will be the proportion of them whose depth of chest

lie between any limits we please to specify?
These statistical laws are now exciting much interest but ~~their present rudely approximative solution~~ at present their solution is only rudely approximative on account of the deficiency of data. Pedigree stock is eminently adapted to supply the manifold ~~deficiencies~~ wants of data which inquirers feel and it is with the hope of ultimately enabling these data to be easily procured, that the present paper is written. It deals with only one aspect, but that the most essential one of the subject in question, namely how to obtain the desired measurements with facility, whatever those measurements may be.

A very little experience made it clear to me that direct ~~measurements~~ of the animals is hardly practicable. A thoroughbred horse ~~is~~ is not the sort of creature to submit tamely to tape and calipers, neither are bulls. On the other hand beautiful photographs are now taken in large numbers of these animals, thanks largely to the rapid plates in modern use, and I have considered how to utilise photography as a means of measuring with the results now to be described.

I first practised myself in measuring certain points on photographs of horses, irrespective of corrections due to perspective, in order to ascertain the degree of precision that was practicable in this way. I made repeated measures of the height at the withers, that at the croup, the depth of the chest and the length of ~~the horse~~ ~~seat~~ the body in the photographs of several different horses, using a 3 inch ~~length~~ lens and a common millimetre scale. The precision was such that an error of half an inch in the actual dimension was never made. ~~Wi~~ sharp definition of photographs would enable a still ~~much~~ higher degree of accuracy to be reached, say to within a maximum error of a quarter of an inch, if micrometric apparatus was used. Consequently in this respect, photographic measurement leaves nothing to be desired.

The next preliminary question to be settled was whether individual variation among race horses, and by inference among other pedigree breeds, was large enough to deserve the trouble of measurement. The only measure that I could make in the photographs that was not more or less vitiated by uncorrected perspective, was the ratio between the height at the withers & the depth of chest. I found this relation to vary notably in the different horses, and I have every reason to believe the same to be the case with the other

[illegible]

measures. It was possible to make ~~since~~ comparisons ~~that~~ between ~~them~~ various dimensions, that were

trustworthy within moderate limits, and after
making ~~full~~ allowance for errors due to perspective, the
~~allowing~~ regarding this uncertainty, ~~still the~~
differences were still large. then the longest body as measured on the ~~photograph~~ was not the same for each horse I have ~~no~~ little doubt
that race-horses could be discriminated and identified by their measurements
almost as ~~easily~~ surely as criminals are identified
by the Bertillon process.

Let us now consider what the measurements
can ~~may~~ be correctly ~~made~~ derived from the single drawing Fig 1. The fig
represents a horse standing ~~on level ground~~
within a graduated square ~~ruled marked upon it~~, of
100 inches (8 ft 4 inches) in the side. The camera
has been pointed squarely to the nearest
side of the square, and the axis of the camera is horizontal
The lines M.M. represent strings with

weights at the bottom, to serve as plumb lines; and which might be ~~there are~~ suspended from supports outside ~~not within~~ the range of the picture. ~~I assume~~ the square plot on which the horse stands is assumed to be level; the picture contains no evidence that this condition has been fulfilled; it would be possible to ~~have~~ ~~cause~~ ~~this verified~~ by introducing into the picture two builders' T shaped levels, such as builders use, one parallel to AY the other to YD that should testify to its horizontality, but it is hardly worth while to do so. ~~In other essentials~~ the picture yields intrinsic evidence that the above conditions have been fulfilled, for ~~thus~~. If the camera had been tilted upwards or downwards the plumb lines would not run parallel to one another in the photograph as they do; if its axis had been ~~inclined horizontally~~ perpendicular to AX, the near lines AD and YD ~~or far sides of the square~~ would not be run parallel in the figure. The height of the camera, C, above the ground is determined ~~shown~~ by the position of the vanishing point, or that at which (convergence) of AY and XD, when prolonged; its

f. 9v

which is CP in fig 2 is found from the ratio of ~~dy to DY~~ RS to DY (figs 1 & 2 RS being the number of graduations on AX that occupy the same perspective width ~~the perspective~~ as DY. In fig (1) y stands at the graduation 14, and d at 84, so dy = 70. By construction DY = 100 and AY = Pp = XD = 100 also

Then $\frac{CP}{CP+CP} = \frac{yd}{YD} = \frac{70}{100}$ whence CP = ~~23⅓~~ $23\frac{1}{3}$

$\frac{10\times70}{100-70} = \frac{700}{30}$ = 23.

to determine the distance, let

Generally, g be a given no of graduations in YD

y the number in AX that have the same perspective width, let P'c = a and P'p = b

then $\frac{a}{a+b} = \frac{y}{g}$ whence $a = \frac{by}{g-y}$ (1)

$ag = ay + by \quad a = \frac{by}{g-y}$

f. 10 9

in the point at
other words, ~~it lies at~~ where the prolongation
AG and DX
of the ~~sides~~ of the ~~square~~ meet. The horizontal distance
of the camera ($\underline{a}$) from the nearest side of the
which is CP in fig 2 noting RS which is in AX
square, is found by the number of graduations, EF,
that which have
~~on that side~~ ~~[illegible]~~ the same length in the picture
as the whole of the side YD
~~as the whole of the further side~~, ~~as any given~~
YR & DS being perpendiculars to YD & AX. (They do not look so in the diagram owing to an optical illusion, due to the diagonal lines that [illegible])
~~number of graduations, ef, on the furthest side~~, for
'RS'

Then $\underline{a} = \cancel{\frac{100'' \times EF}{ef - EF}}$ YD $\dfrac{EF \times 100''}{ef - EF}$ RS. (Fig. 2)

in the picture, with YD = 100, EF = 70. consequently AR = 14, AS = 94 ∴ RS = 70
thus ~~if EF = 40", ef = 60"~~, then $a = 200''$ $\frac{7000}{30} = 233.3''$

When
~~If~~ the graduations are sharp, and the distance CP $\underline{a}$
is only 2, 3 or even 4 times as much as great AY ~~100"~~, its value
can be determined by this method with much
precision.

(Displace this to p13)

f. 11 9

To return to the picture, we see from the position of the ears that the head of the horse is turned to us, and there is no sure guide to tell us how much. A vertical plane passing through the camera and the horse's eye will cut the ground in the line shown in the picture, so a vertical line dropped from the horse's eye ~~to the ground~~ will reach it the ground somewhere in the course of that line, but where, we cannot tell with certainty though we may infer where within limits. The position is indeterminate, consequently from these data alone the height and position of the eye in space cannot be calculated. This difficulty will be surmounted ~~later on~~. by

~~It is different as regards the height of the~~

F. 12 (10)

Returning to Fig 1 we see that the height of the withers, that of the croup, and the depth of the chest and other points which are situated either on the spine of the horse or in the same vertical plane with it, admit of measurement because the inter section of that plane with the ground is determined by the position of his feet, and that intersection affords the needful basis for the measurement. The fore feet of a horse when he is standing still, are placed near together; Sometimes they often touch, they are never more than one hoof's breadth apart, say 4 or 5 inches, unless the animal is straddling in an ungainly way. Similarly as regards the hind feet. Therefore by dotting as has been done in fig 5, the ~~the figure~~, corresponding parts of either pair of hoofs (notice the short cross lines), joining the dots, bisecting the distance between them, & drawing a line through those bisections, we obtain the intersection (MN) ~~of~~ with the ground of the vertical plane that ~~passing~~ through the spine of the animal ~~and the ground~~. This is shown the dark line ~~shown~~ in Fig I. A vertical perpendicular line HK dropped from any point H in the spine, as ~~from H~~ down to this line, ~~namely HK~~, ~~the withers, dropped on~~ MN the ... measures its height of H from the ground, subject only to the correction for perspective; which ~~the amount of this correction~~ is easily calculated as follows. (Scale of AX measuring .. units of the ...)

HK fig 2 is the ~~height~~ measured the height in the picture, ~~ascertained~~ as just described, (k having been found) it is desired to project this HK upon the vertical place running through the side of the square that faces the camera, to be measured there by ~~its scale~~; ~~hk~~ is the projection in question and $\underline{d}$ is ~~the~~ PC distance of ~~k~~ the camera from the scale.

f. 13v

a = horizontal distance of camera from the nearer ~~edge~~ side of the square plot

** b = length of side of ~~square~~ plot (here = 100")

* c = height of object glass of camera above the ground

\+ d = horizontal distance of a given ~~object~~ point ~~behind~~ the nearest ~~edge~~ side of the square plot

δ = length of the projection of d on the plane of the photo ~~picture~~

* g = length of any ~~some~~ given interval ~~number of graduations~~ on the further edge of the square as measured by the graduation on that side.

* y = the number of graduations in the nearer side of the square whose span is perspectively equal to g

\+ S' is the point on the ground that lies vertically beneath the point S

† s = the vertical height of ~~any given point above the ground~~ S, that is the distance between S & S'

σ = the ~~pse~~ length of the projection of S on the plane of the photo ~~picture~~

The values marked by ~~an~~ a double asterisk ** is given, a single ~~... ...~~ by the construction. The 3 values marked by a single asterisk c g y are ~~given or else~~ found by drawing ~~...~~ 4 lines in all. The 2 values d ~~and s~~, ~~and s~~ depend on S'. ~~These~~ The values marked with a cross +, ~~namely~~ ~~d and s require the determination of the base of the vertical. This is~~ S' is found 3 lines in all, viz a single vertical ~~effected~~ by drawing ~~two~~ lines in each photograph from the point S, showing where the line in the second ~~&~~ then transferring ~~the~~ cuts the sides of the plot, & ~~line from the~~ second photo ~~one~~ on to the first photo ~~other~~, the intersection of ~~the two lines~~ it with the line already there giving S'

~~The remaining 3 values~~ d & ~~σ~~ S are then measured off

Of The remaining 3 values a, δ, σ, are given by the following equations. Of these, a is the same for all points S in the same picture, leaving δ & σ to be calculated for each point.

In short the full determination of any point S requires the drawing of 7 lines and two simple calculations, besides its share of the a third equally simple calculation

total 4 + 3 7 lines

$$1 \qquad a = \frac{by}{g-y}$$

$$\sigma = \frac{Sa}{a+d}$$

$$3 \qquad \delta = \frac{dc}{a+d}$$

$$2 \qquad s = \frac{\sigma(a+d)}{a}$$

δ is only wanted supposing no ~~network~~ criss cross scale pattern is available to measure with

$HK = H'K'$ and $hk = h'k'$. When HK is moved parallel to AX to any new position $H'K'$ its projection $h'k'$ will remain unaltered. Let the perpendicular distance of K or K' from AX which is equal to $K'P$, be called t, & the perp. distance from camera to AX be called a 12

Then $h'k' = H'K' \times \dfrac{a}{a+d}$

consequently $hk = HK \times \frac{a}{a+d}$

In the fig. I $d = 11''$ as read off on the side scales. $= PC$

$HK = 53''$ as read off on the front scale, Consequently

$hk' = 53'' \times \dfrac{233.3}{243.3} = 53'' \times 0.96 = 50''.9$

So again the measured depth of chest in the picture, HI a portion of HK and representing

is $24''$, consequently its real measure is $24 \times 0.96 =$

Such calculations as these are rapidly performed

either by a sliding rule or by Creil's Multiplication Tables.

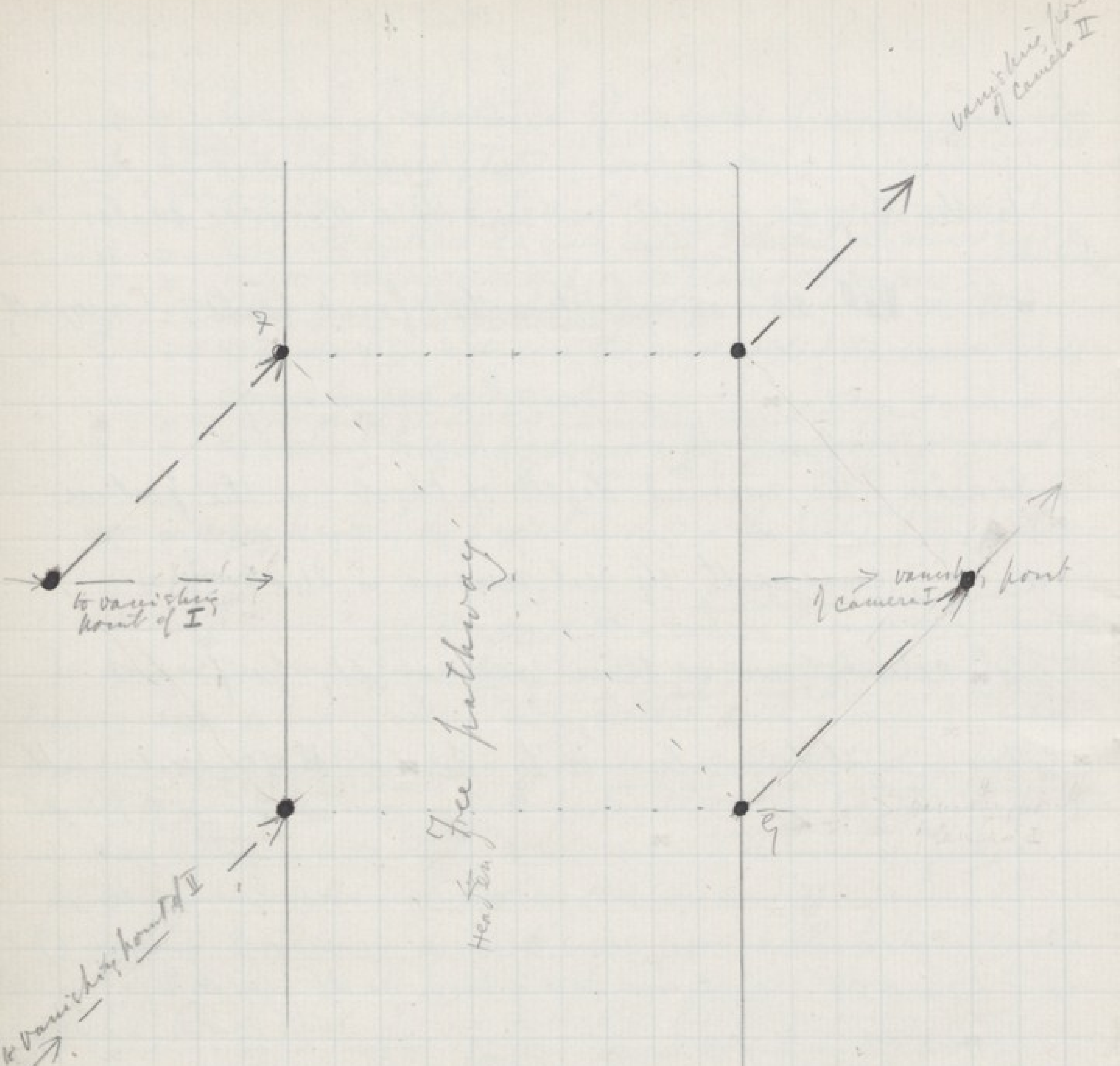
Generally s = stature in picture as shown by HK

σ = its projection on the plane reference plane, as shown by hk

d = distance PK' = horizontal distance of HK from AX

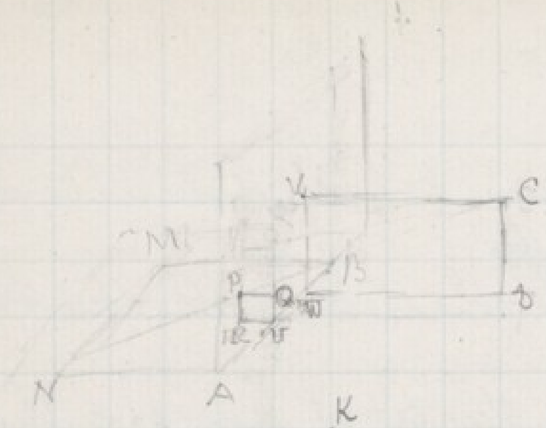
then $\dfrac{\sigma}{s} = \dfrac{a}{a+d} \qquad \sigma = \dfrac{sa}{a+d} \qquad (2)$

f. 145



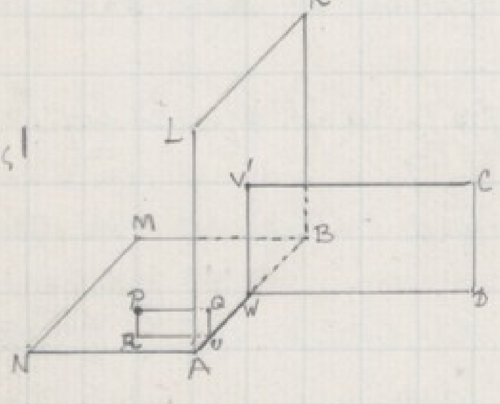
divide 7g into 10 equal parts & draw lines through them from vanishing points to sides of plot. These graduate the sides

(Begin with page 9)
by using two cameras and taking simultaneous views, ~~or~~ say by working ~~both~~ i.e. the shutter of one, ~~with the same one by~~ a pneumatic ball held in the right hand & that of the other with ~~one~~ a ball held in the left, and squeezing both ~~together~~ at the same moment. The axes of the two cameras might conveniently be ~~about~~ inclined ~~to~~ some 45° to one another, ~~if much~~ li



C & D are S & T respectively with article Encycl Brit.

Fig 1



ABMN the square {platform / plot}

ABKL the picture plane

AB the {base line / ground line / fundamental line}

C centre of object glass of camera

CD the height above ground

V the vanishing point

CV being perpendicular to picture plane

P any point in space, above platform

R the foot of the perpendicular PR from P to platform

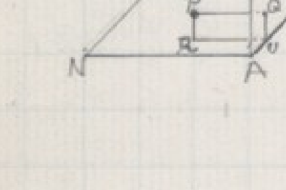
PQ a perpendicular from P to the picture

RU " " R " "

P_1 P_2 P_3 be different points in space

P'_1 P'_2 P'_3 be their perspective positions in the picture

The general problem is:- given P', to find P.



E F for the 5th & 6th points for Photo 2.

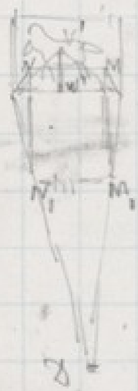
Square Plot with its corners marked by pegs level with the ground & capped with white
a Plumb line ⟂ attached behind the plot within range of the picture

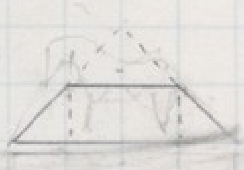
Plot or platform quite level } by construction
Its pegged out corners an exact square of known size say 100" in side }

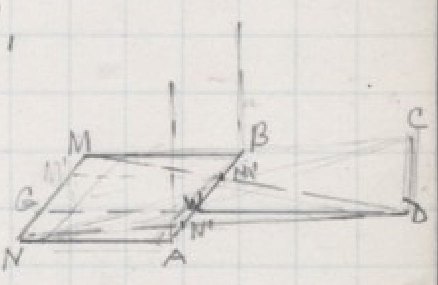
Plate of Camera parallel to picture plane. i.e. to both AB & to BK
(its parallelism to AB being verified by A'B' being parallel to AB
" " BK " " by ⟂ cutting AB (produced if needed) perpendicularly

The photo bears intrinsic evidence whether or no this is the case

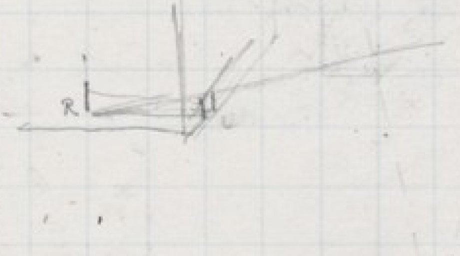
All points along AB are identical ~~both~~ in reality & in picture.
V' is the point of convergence of A'N' & B'M' fig 2,
whence V'W' is found by measurement in terms of A'B' which is identical with AB
δ is the point of convergence of ~~d~~NM with N'M' as measured on A'B'
that is in fig 2 with $N_1 M_1$







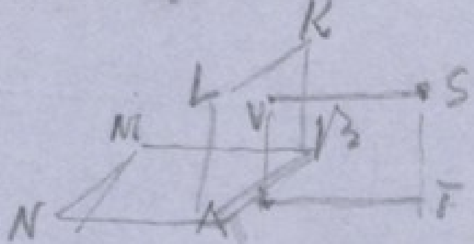
$$\frac{MN}{MN'} = \frac{\delta G}{\delta W} = \frac{\delta W + AN}{\delta W}$$



f. 16ar

$$
\left.\begin{aligned}
l &= 12 \times 1.5 \text{ inches} = 18 \text{ inches} \\
a &= 2.5 \times l = 45.0 \text{ inches}. \\
c &= 0.87 \times l = 16.66 \text{ inches}
\end{aligned}\right\}
$$

S = Point of sight = Camera



ABKL the picture plane

ABMN Horizontal plane = ground plane

AB = { ground line
Base line
fundamental line

SV ⊥r to picture

V = { centre of vision
" ~~picture~~

ST = height of eye (camera

The vanishing line runs ~~the~~ horizontally through V
is called the horizon
& contains the vanishing points
of all lines parallel to SV
that is ⊥r to picture plane

"The foot of the perpendicular"

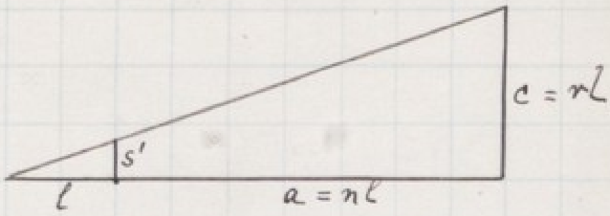
= ABC in space
lines drawn through ~~them~~ from
V cut picture plane in A', B', C' &
= distance of a point P behind the picture frame" over

(turn over) (2) f. 16bv.

Q is the point where
a perpendicular from
P cuts the picture frame
(so QP is horizontal)

QR ~~seems to be~~ is the
distance of Q behind
the picture plane

Relation between c and a
for given values of $\frac{l}{s'}$



$$\frac{l}{s'} = \frac{l(n+1)}{l \quad r} = \frac{n+1}{r}$$

let $\frac{l}{s'} = 5$ then $5r = n+1$ " $r = \frac{n+1}{5}$ $\underline{l=10}$

$n = 2.0$ $r = \frac{3}{5} = 0.6$ $c = 0.6 \times l$, $c = 6$
$n = 2.5$ $r = \frac{3.5}{5} = 0.7$ $= 0.7 \times l$ 7
$n = 3.0$ $r = \frac{4}{5} = 0.8$ $= 0.8 \times l$ 8

let $\frac{l}{s'} = 6$ then $r = \frac{n+1}{6}$

$n = 2.0$ $r = \frac{3.0}{6} = 0.5$ $0.5 \times l$, $c = 5$
2.5 $\frac{35}{6} = 0.58$ $0.58 \times l$ 5.8
3.0 $\frac{40}{6} = 0.67$ $0.67 \times l$ 6.7

$\frac{l}{s'} = 4$ $r = \frac{n+1}{4}$

$n = 2.0$ $r = \frac{3}{4} = 0.75$ $0.75 \times l$, $c = 7.5$
2.5 $\frac{3.5}{4} = 0.87$ $0.87 \times l$ 8.7 +
3.0 $\frac{4}{4} = 1.00$ $1.00 \times l$ 10.0

* There are photo Dec. 5/95
c = 15.66 inch
a = 45.0 "

$$(3) \quad a^2 + a(d-2f) = fd - f^2 + f^2\frac{d}{r}$$

when d is infinitely large this becomes $ad = fd + f^2\frac{d}{r}$

$$a = f\{1 + f\tfrac{1}{r}\}$$

$f = 5$ inches $\quad r = \frac{1}{100} \qquad a = 208$ feet 9 inches

$$(4) \quad a = \sqrt{\left\{f^2\frac{d}{r} + \frac{d^2}{4}\right\}} - \frac{d}{2} + f$$

$d = 50 \quad f = 5 \quad r = \frac{1}{100} \qquad a = 334$ inches $= 27$ feet 10 inches

from (3) $\quad -(5) \quad r = \dfrac{df^2}{a^2 + a(d-2f) - fd + f^2}$

feet
$a = 30$ =

Call diagonal 12 feet (it is a trifle less), $d = 144$ in

$d = 6$

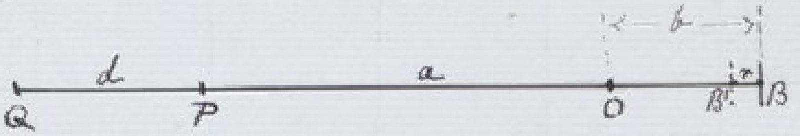
$df^2 = 144 \times 25$

$\frac{1}{2}d = 3$

$a' = 33$

12/334 (27
24
94
84

I sent a copy of this to T. R. Dallmeyer Dec 15/95



O is the optical centre of lens
P the nearer side of plot. Q the further side.
B the back focus of lens when P is the front focus
B' " " " Q "

$OP = a \qquad PQ = d \qquad OB = b \qquad OB - OB' = r$

f the equivalent focus of lens

Required $\underline{a}$ in terms of $\underline{d}$, $\underline{r}$ and $\underline{f}$

(1) $\quad \dfrac{1}{f} = \dfrac{1}{a} + \dfrac{1}{b}. \qquad b = \dfrac{fa}{a-f}$

(2) $\quad \dfrac{1}{f} = \dfrac{1}{a+d} + \dfrac{1}{b-r}$

Substituting in (2) the value of $\underline{b}$ from (1), we get

(3) $\quad a^2 + a(d-2f) = fd - f^2 + \dfrac{f^2 d}{r}$

If $\underline{d}$ be infinite the terms not containing it disappear, leaving

$$ad = fd + \frac{f^2 d}{r} \quad \text{or} \quad a = f\left\{1 + \frac{f}{r}\right\}$$

take $f = 5$ inch, and $r = \frac{1}{100}$ then $\underline{a} = 5(1+500) = 2505$ inch
$= 208$ ft quickly

after which distance all objects are sensibly of same focus

from (3) we obtain

(4) $\quad a = \sqrt{\left\{f^2 \dfrac{d}{r} + \dfrac{d^2}{4}\right\}} - \dfrac{d}{2} + f$

take $d = 50$ inch $f = 5$ inch $r = \frac{1}{100}$

$a = \sqrt{(125156)} - 20$ ~~= 374 − 20 = 374 inches = 27 feet 10 inch~~

= 354 − 20 = 334 inches = 27 feet 10 inches

P, Q, are two points at the respective distances of $\underline{a}$ and $a+d$ from the optical centre of the lens of the camera, whose equivalent focus is f.

When the camera is focussed on P, let its back focus be $\underline{b}$; when focussed on Q, let its back focus be $b-r$

Given f, d, and r, to find a

we have

$$\frac{1}{f} = \frac{1}{a} + \frac{1}{b} \qquad (1)$$

$$\frac{1}{f} = \frac{1}{a+d} + \frac{1}{b-r} \qquad (2)$$

substituting for $\underline{b}$ in (2) we have $\frac{1}{f} = \frac{1}{a+d} + \frac{a-f}{af - \cancel{ar} + rf}$

whence $a = \sqrt{\left\{\frac{df^2}{r} + \frac{1}{4}(2f-d)^2 + df - f^2\right\}} + \frac{1}{2}(2f-d)$

which differs little from $a = \sqrt{\frac{df^2}{r}} = f\sqrt{\frac{d}{r}}$ in the cases with which we are concerned viz where $r = \frac{1}{100}$ inch. $= 10f \times \sqrt{d}$

Take $f = 5$ inch, $d = 30$ inch, $r = \frac{1}{100}$ inch

$\sqrt{\frac{df^2}{r}} = \sqrt{75000}$ $\qquad \sqrt{750.00} = 274$ inches $= 22$ ft. 10 in

$f = 5$, $d = 5$, $r = \frac{1}{100}$ inch (for my model)

$a = \sqrt{5 \times 25 \times 100} = \sqrt{12500} = 112$ inch $= 9$ feet 4 inches

write it thus

whence $a = \sqrt{\left\{\frac{df^2}{r} + \frac{1}{4}(2f-d)^2 + df - f^2\right\}} - \frac{1}{2}(d-2f)$

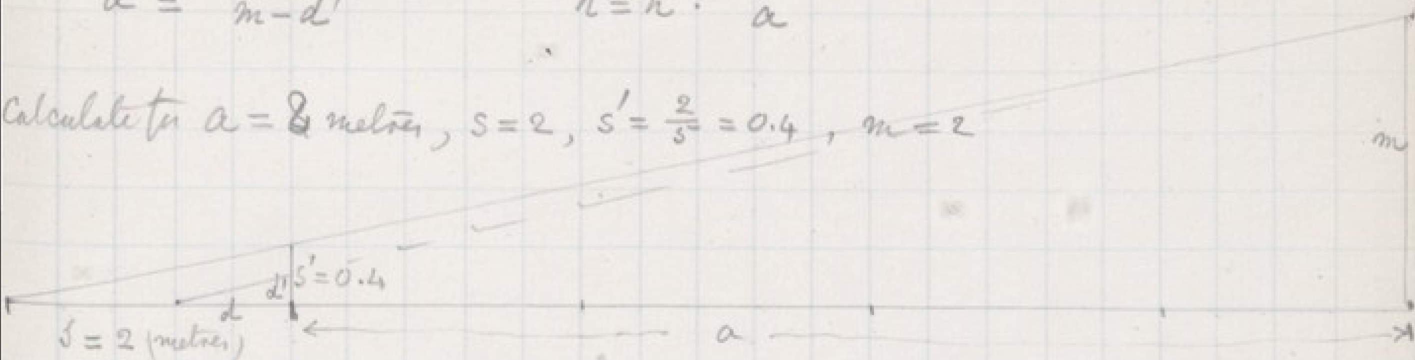
(the first of the terms under the square root so largely exceeds the others (when $r = \frac{1}{100}$) that the latter may be neglected; in ~~which~~ this case we have

$a = 10f\sqrt{d} - \frac{1}{2}(d-2f)$

or for approximate purposes when d is much smaller than a, ?} $a = 10f\sqrt{d}$

$$d = \frac{a d'}{m - d'} \qquad h = h' \cdot \frac{a+d}{a}$$

Calculate for $a = 8$ metres, $s = 2$, $s' = \frac{2}{5} = 0.4$, $m = 2$



d'	d	(x^{le} of h') $\frac{a+d}{a}$
$s \times 0.1$	0.16	1.02
.2	0.33	1.04
.3	0.51	1.07
.4	0.70	1.09
.5	0.89	1.11
.6	1.09	1.14
.7	1.30	1.16
.8	1.52	1.19
.9	1.76	1.22
1.0	2.00	1.25

Great distortion through perspective

Objection to perspective yes, converse no (surveying, levelling?)

Results reached are simple though many points must be considered.

They enable us to measure photos of animals of all kinds, whether it be to investigate the attitudes in locomotion of many that are simultaneously photoed or ~~Horses &~~ pedigree stock for breed. invest^g. Their application is otherwise wide

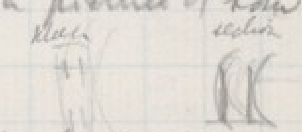
the required conditions are ~~[illegible]~~ a plot of level ground, say, for horses, 10 ft by 6. with at least 2 marks, such as bricks let into the ground & level with it to serve as fiducial marks in the photo, for the scales. Two solid cameras on solid pedestals fixed & focussed once for all, & working simultaneously, and all distances carefully measured

The position of any point P that is visible in both photos is found by 3 ~~[illegible]~~ simple operations, The two first, the ~~[illegible]~~ determines Q, the foot of the perpendicular dropped from P on to the ground, the second gives the multiple to be applied to the measured distance (in the photo of QP) to obtain its real value

For certain important measures, because in these cases, a single ~~the~~ photo ~~itself~~ contains data for determining Q ~~[illegible]~~ (the second camera is unnecessary) Explain that at 30 feet 1 foot nearer or further Q makes $\frac{1}{30}$ diff^ce in height, ~~[illegible]~~ making 2 inch differ. in 6 ft at withers

The negatives & the proposed photos would be small, a horse's withers will be only 1 inch high; they would be printed from in an enlarging camera to, say, 2½ times the original scale, producing for a horse a picture of say 2½ inches in height at the withers;

picture horse 2½ inch high at withers



(1) Accuracy of measuring photos pricked

(2) Size of plot, distance from cameras such that objects in it shall be sensibly at same focus (Eg: distance from cameras: focus = f width 5 feet) 8 feet

(3) Foreshortening of plot to $\frac{1}{5}$ given height of cam

(4) Mechanism: - of Camera, of ground plan, scale of frame work plumb line

(5) Picture of vacant plot & accessories contains internal evidence of adjustment of camera, not of level or of scale except

(6) Formula - - scale constructed from them, example.

(7) Measurement where a single camera is used

(8) " when the second - -

~~[illegible]~~

~~to~~

~~[illegible]~~

f. 1v

Though Anthropology ~~in its sense~~ may be said to includes all humanity & all human activity, ~~but~~ it has here a much more restricted practical application which is adequately

The ~~range~~ subject are here included under the title of Anthropology ~~as fall~~ are those that are recognised as falling within the province of the ~~numerous~~ existing Anthropological and Ethnological Societies and museums, ~~[illegible]~~

The scope of Anthropology is ~~sufficiently defined by that~~ coextensive with the subjects of ~~the character~~ of the ~~memoirs~~ memoirs & studies accepted ~~published~~ by the numerous Anthropological & Ethnol. Societies and museums ~~as falling within their province~~ Manufactures ceremonies social life & religious customs

In these, the social customs ~~[illegible]~~

~~[illegible]~~ ~~apply~~ here dealt with one almost wholly ~~to~~ those ~~races~~ races of uncivilised, which ~~have not yet conformed to western civilisation~~ are studied ~~as~~ by anthropologists because therefore ~~retaining~~ peculiarities ~~that~~ and which throw light on the course of human development

~~For indexing purposes~~ It seems convenient to give a separate ~~number~~ heading section to Prehistoric Man

The list of subjects ~~introduced~~ added to the subsection merely to ~~show the~~ illustrate the character of the topics that fall under each secondary head — no attempt has been made either ~~here~~ to group them into classes treat them exhaustively or

In these ~~It is convenient for indexing purposes to make a special class for~~ man

590 – 599 ANTHROPOLOGY f.25

591 – Anthropometry

2 – Prehistoric man

Races & their peculiarities (arranged according to their
3 – ~~Ethnology~~ (geographical distribution) ~~of races~~

Epochs in human life and the associated
4 – Vital ~~epochs and~~ ceremonies among uncivilised races

~~5~~ Dwelling, structures and dwelling places

occupations
5 ~~6~~ ~~Social life~~ and industries (comes with 5) of uncivilised races
6 Art of uncivilised races

~~7~~ – Religions, and Laws and Customs of uncivilised races

8. – Unclassified matter

GALTON/2/8/7/1/3

Callipers sliding compasses, measuring rods, scales, color forms

~~Craniometry stature weight dimensions~~. criminal anthropology contours

Standard color forms & [illegible] chart (see psychophysics) psychometric apparatus statistical methods) application ~~criminal anthropology~~ & ~~development~~ identification

Measurement of skull pelvis limb bones precocity Insanity Lunacy

chest, endurance of temperature voice

Head face & body limbs hair skin teeth

attitudes & movements

sight test-dots. color sense hearing smell & taste touch

physical powers ~~endurance~~ of strength speed accuracy of arm odour voice psychology mental powers
~~Criminal anthropology~~

Tattooing marks abnormal hairiness & the reverse deformities of face extremities steatopygia
albinism [illegible] . [illegible] ear excessive [illegible] [illegible] recuperative powers

giants dwarfs .

of skull, & [illegible] of [illegible] , of nose, cheeks, lips & ears - noses scars (see tattoo)
partial or complete castration
chipped teeth - breasts - feet , amputation of a finger

Published tables of

591 Anthropometry

1.35 1

591.1 Instruments and methods. — Callipers, measuring rods, weighing machines, psychophysical apparatus. Standard colours for skin hair-eyes. Statistical methods — for Criminal identification (see Systems)

.2 Anatomical & physiological. — measurements of skull, bones of body, pelvis, limbs, ~~changes during development~~. Correlations of measurements. Sex differences, Odour

.3 Form and feature of living person. Head measures — body limbs, changes during growth, skin, hair, teeth, gesture — voice

.4 Faculties, ~~Psychophysics~~ psycho sight color sense hearing, musical powers, smell taste touch, muscular power, endurance of fatigue, pain, temperature, accuracy of aim, mental powers. recuperation power

.5 Natural variations. albinism, erythrism — hairiness, giants dwarfs, natural deformities of face, extremities, steatopygia

.6 Deformations of skull, nose cheeks lips & ears, raised scars, chipped teeth, of breasts, feet, amputation of finger, (castration circumcision (hypospadia))

~~Tables of human measurements~~

.7 ~~Statistical results~~ Tables of human measurements

.7 Museums & collections

Palaeolithic Neolithic Recent

Megalithic monuments, tumuli, entrenchments

Stone implements how fashioned by sawing, flaking & chipping grinding boring
Weaving basket pottery hooks nets

Geological evidence of antiquity

592 Prehistoric Man f. 45 2

592.1 Origin and antiquity of man

.2 Localities where remains ~~exist~~ have been found
according (Geographical catalogue)

.3 Physical ~~description~~ peculiarities and homologies

.4 Dwellings & ~~structures~~ caves, pile dwellings, megalithic monuments tumuli
entrenchments

.5 Industries Stone implements & their manufacture, weapons, fishing gear, pottery weaving (see)

.6 Contemporary animals & plants. their use for food, cannabalism
wild animals

method of
Search & verification & collection

Collection
7 Collections

migrations

593 ~~Ethnology~~ ~~Geographical distribution of Races.~~

Races & their peculiarities, (~~distributed~~ classified according to their homes)

593.1 General

.2 Europe

.3 Asia

.4 Africa

.5 America North

.6 America South and Central

.7 Australasia & Oceania

.8 outlying Islands

widely diffused races

f. 5r

Practices associated with Vital Epochs

umbelical cord
Circumcision - ~~artificial hypospadia~~ deformation of head. name giving
fate of twins, infanticide .. time of suckling.

closure of vulva   menstruation   age of puberty   sexual indecency
initiation

exogamy endogamy
polygamy polyandry promiscuity   couvade   anticipation of labour - purification

artificial hypospadia
of half castes   average fertility - multiple births - any restraints or prop. of abortion

consumption. fever   small pox   epilepsy   snow blindness
Scurvy   leprosy   opthalmia   syphylis & its signs   endurance of pain   vital power   toothache
charms   medicines   surgery   fractures   trephining. drugs   exorcisms | contact with civilisation
insanity - amok   idiots   exceptional malformation

extreme old age reported. are old people killed - or sick ones

Sacrifice of widows - putting old to death - the sick.
Ceremonies at death - at burial place - cremation - mummies &c

~~Half castes~~, their faculties

594 f.6r 4

Vital epochs and Ceremonies

Epochs in life and associated ceremonies in uncivilised races

.1 Birth and infancy umbelical cord. infanticide
deformation of head, circumcision namegiving time of suckling

.2 Puberty pageants, initiatory rites

.3 Marriage. polygamy. polyandry exogamy & endogamy marriage by capture

.4 Child bearing) anticipation of labour couvade purification

.5 Fertility. average, multiple births fertility of half castes
restraint on population – artificial hypospadias, abortion (infanticide 594.1)

.6 Disease, medicine, surgery Prevalent diseases? Infantile small pox vital powers effect of contact with civilisation
insanity excision imagination parasites
drugs charms. fractures trephining

.7 Longevity: killing the old or the sick, average & for
extreme & precocity

8 Death and burial Putting the old or sick to death
ceremonies at death at burial place cremation
mummies

X ~~Heredity~~

f. 6v

underground houses roofed

Dwellings in trees - villages stockades & fireplaces & decoration before building

Tents yurts wattles thatch bark mud

burial in hut

(Econ) **Dwellings, structures & burial places** f.75 5

(see Prehistoric man) insert in 6

- Caves

- Huts and houses

- Pile Dwellings

- Tents

- Cairns and burial places

- Cromlechs &c

- Unclassed

f. 7v.

with birds &c
Driving of game. Pitfalls - with dogs - hawking

Snares & foot traps   fish spears hooks harpoons net traps

dugouts bark & skin canoes
Boats, sails, paddles anchors rafts   Swimming diving

armour war paint spears bows-arrows poison throwing stick stones slings
clubs daggers swords shields Horse equipment. Fortifications. Causes of war
fire balls & arrows

Hoe Plough, domestic animals, milk, herding
mattock sickle. Garners grain & other food   land marks purity of Breed

& equivalents
money weights & measures of length surface & capacity   lotteries
Ferries Bridges roads - Path finding
tolls

clothes head covering. dressing of hair. ornaments to face, body hands legs & feet
weaving, method of, felts bark cloth   Basket work   String animal fibre, seeds, reeds,
Preparation of skins   Raw hide uses of   Feather work   Pottery - substitutes (e.g. gourds, shells)
Dyeing - dyes used   Painting   Stone implements see Prehistoric   Metallurgy, bellows blowpipe furnace
blacksmiths, Bamboo work (see 592.5)

pigments staining nails, tattooing & methods   carved figures, idols
designs in ornamentation   inscriptions   paper a use of

Music instruments airs, Dances. Games - Poetry   gambling toys Amusements
races & competitions

~~Masks~~, pictures, Knots or notches, marks on rocks, bark skins   hieroglyphs
idols
Cattle marks, cyphers. maps   Signs of taboo. Numerals. Peculiar sounds, gestures, deaf mutes

Fish - flesh, cereals &c   milk   cannibalism
tobacco & substitutes -
Eating dirt   craving for salt   cooking. sacrifice prohibition
drinks, etc

595 ~~Social life and~~ industries of uncivilised races 6

(interl (5)) 1 Dwellings structures and burial places

2 Hunting fishing and war
implements snares pitfalls traps spears throwing sticks bows throwing clubs daggers swords poison arrows armour shields war paint
dogs & other animals used fish spears hooks harpoons nets ~~[illegible]~~
hook shellfish — Causes of war — Division of spoil

3 Pastoral agricultural and mining

4 Food and Stimulants Fish flesh vegetables milk cannibalism
intoxicating drinks - salt, drugs opium hemp tobacco &c eating

5 Trade and transport
boats dugouts bark & other canoes rafts &c paddles anchors

6 Handicrafts & ornamentation
clothing thread netting sewing stone implements emery needles weaving bark cloth felts skins
Basket dyeing Paints
Pottery & ~~[illegible]~~ lamps
Metallurgy bellows blacksmith

7 Drawing painting and carving

8 Amusements
theatrical gambling
swimming diving

9 Communication of ideas

~~Food and stimulants~~

Occupations & industrial life
(1) War & hunting
fishing & navigation
Pastoral & agriculture
7 dwellings
Food
Stimulants
Clothing
Dwelling food & clothing
8
(2) Continued
Handicrafts &
utensils

Occupations & industry
war fish Past Agr
mechanical Handicrafts undistinguished
other Dwelling Food Clothing

Industries
Occupation & Industries
Handicraft
war — Dwelling
fish — Food
Past — Stimulants
Agr — Clothing
Handicrafts — utensils
other — Handicrafts

Dwelling
Food
Stimulants
Clothing & tools
Ornamentation
Drawing
amusement
com. of ideas

Ornamentation
Drawing
amusements
com. of ideas

Art
ornamentation Dyes
Drawing
amusements
Comm. of ideas
Division of time - divisions stars seasons
Astronomy

f. 85

Totemism. [illegible]

Nature myths, eponymic heroes, descent of man, golden age [illegible] of death

spirited away, lazy ghosts, apparitions   magic
Connection with morals – Souls – wraiths, sacrifices at funerals, vampires, oracles, fetishes, idolatry
Evil eye, auguries, lucky & unlucky objects, dreams
what beasts &c worshipped – divine ancestors. sacrifice of widows, infanticide, memorial structures

Priests, mysteries, festivals, prayer, sacrifices, austerities, prostration, fasting & narcotics to produce dreams

Taboo Homicide, manslaughter, theft, adultery, for right & wrong. duties to own tribe, to others. (marriage prohibitions O.S.)

Chiefs & their powers,
Covenants – blood, ordeals, torture to gain evidence. Secret judicial societies, appeals (slavery see 8)

Retaliations death mulcts slavery

Land tenure, Game,

How relationships named & estimated – genealogies

Castes, Tribes & clans, permissible intermarriages. badges & marks. Stories of their origin

596 Religion, law and custom (of uncivilized races)

.1 - Mythology (Totemism

.2 - Religion, superstition, and ceremonies

.3 - Prohibitions and crimes

.4 - Judicial and legislative processes

.5 - Punishments

.6 - Property

.7 - Relationships and inheritance

.8 - Social status and slavery

f. 9

Unclassed

we find that Q lies somewhere in the line $M_2 q_2$ produced. Consequently the intersection of the two lines determines the position of Q. Draw a perpendicular from the plan on to AB produced cutting it at X. Then AX (regarding its sign) $= x$, $XQ = y$. These determinations are independent of the heights ~~of the~~ of the cameras N_1 N_2.

To determine $z = PQ$, ~~first~~ ~~measure~~ first find $P'Q'$ in the picture $p'q'$ p_g' ~~from~~ its photographic ~~equivalent~~ representation $p'q'$

$P'Q' : AB = p'q' : ab$ or $P'Q' = \frac{p'q'}{a'b'} \times AB$

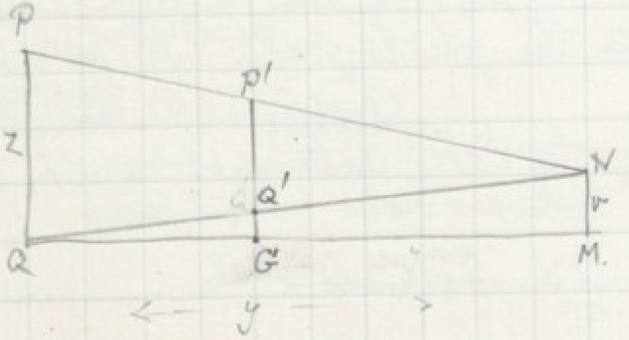
Now $P'Q'$ is composed of two parts (1) $Q'q'$ which is the projection on the picture plane of the horizontal line QQ' as seen from N which is raised from the ground $NM = v$

$QQ' : NM = x : x+a \qquad QQ' = \frac{xv}{x+a}$

so $P'q' = \frac{p'q'}{a'b'} \times AB - \frac{xv}{x+a}$ & $PQ =$

f 10r

In the fig MG = a = distance of M from AB
MQ = y   MN = v = the height
of the camera



we first find P'G, then Q'G & then PQ

~~we first~~ ~~measuring~~ p'g' and ab are measured on the photographs

then tan P'G : p'g' = AB : ab   P'G = $\frac{p'g'}{ab}$ AB   where MG = the perpendicular distance from M to AB & also MQ = y

laying this down as in the figure, join NQ cutting P'G at Q'

then Q'G is the projection of the horizontal length QG upon the picture plane, and the remainder Q'P' is the perspective view of QP. Erect a perpendicular at Q join NP' & prolong the line until it cuts the perpendicular at P, then PQ = Z

~~vert~~ plane that passes through P and N cuts CB

in the photograph fig 3 at right angles. ~~Therefore~~ So

in order to find q' on the photograph prolonged ~~AB~~ ~~making and drop on to it~~ draw a perpendicular

P'X ~~is dropped from P' on to AB cutting it at X. at~~ produced to O where ~~making~~ AO = AB

~~on the one side and then~~

~~measuring a distance OX from O~~ Then marking

~~O so that OA = AB and measuring OX we have the~~

~~true value of OX =~~

PX on to it & measure A'X' (regarding its sign). Then

$A'X' : AX$ (in the plan of the installation) $:: A'B' : AB$

or $AX = A'X' / A'B' \times AB$ $\quad AX = \dfrac{A'X' \times AB}{A'B'}$

Laying down X on the plan & drawing the line from M through q', we know that the projection of P on to the horizontal plane, that is to say Q lies somewhere in the line Mq' produced.

Proceeding in precisely the same way with fig 4

(together with the optical lines with which we are concerned)
complete

Fig 5 ~~shows~~ gives [H] a perspective view of the installation)

It consists of three planes)

in action, ~~in which~~ (1) the points Q C x q' B, M ~~are all in~~
is horizontal" & includes)

~~the plane of the horizon~~ ; (2) is vertical & includes the points C x q' B Q' P' ~~are~~ (See to the varying points in the object being the perspective picture of the object, which are because the lines drawn from the intersection of

This is technically called the picture plane and cuts (reproduced on a much smaller scale with camera)

~~all in a vertical plane, cutting~~ the horizontal plane

along the line

~~of~~ C x q, B, which is technically called the 'base line',

the base line

Being common both to the object & to the picture, ~~it~~

divided (a scale of equal parts, as)

~~can~~ may be graduated into inches, and be used as a measure

both for the object generally, and for all points in the

Every subject that includes 2 known points as AB in the base line contains its own scale, & a point say A that will serve as a centre of coordinates & a direction AB that may be used as the axis of a coordinate AX

picture plane (3) is also vertical and passes through

P'Q'q' which lie in

P & N, it therefore includes PQ, NM, also the line of

its intersection with the picture plane

Both PQ and P'Q'q' are ~~both~~ by construction perpendicular

to the horizontal plane; & therefore P'Q'q' is perpendicular

to every line in that plane which passes through q', of

which the base line Cq'B is one ~~of these~~. Therefore the

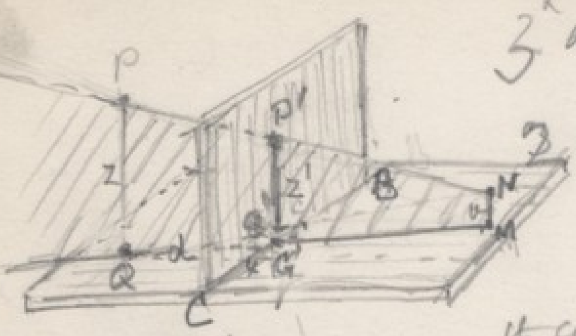
f. 184

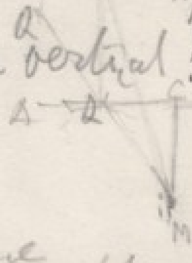
3 Planes in picture perspective:—

1. the plane of the horizon

2. a vertical plane passing through P & the camera cutting (1) along

3. a vertical: forming the plane of the picture cutting (1) in $A\hat{C}B$





3) PQ, P'Q'q', NM are all in the same vertical plane passing through PQ & the Eye (or camera)

1 Q, Aq'B, M are all in the plane of the horizon—

2 A, P'Qq, C B are all in the (vertical) picture plane

AQ'CB is the intersection of the picture plane with the plane of the horizon & is called the base line

P'Q' being $\parallel$ to PQ is $\perp$ to the plane of the horizon & to every line in it that passes through Q', such as AQ'CB

consequently P'Q'A and P'Q'B are right angles

P the detached point

PQ a perpendicular from P, meets the horizontal plane at Q

N the (camera) eye

M a perpendicular from N meets the hor: plane at M

The object is to find Q upon a map of the installation

f. 43

f. 44

least $3 \times 65 = 195$ inches say 200 inches $= 16\frac{1}{2}$ feet.

and AB is taken as 100 inches $= 8\frac{1}{3}$ feet. ~~it could~~ it might be somewhat prolonged but considering

that the ~~area of the~~ complete image is ~~photograph~~ is a circle &

that the maximum length allowable for AB in the image

is a chord of the circle some distance from the centre ~~and~~ something as is ~~in some such position as that~~

shown in Figs 1 & 2, it is well to keep AB well within the greatest possible ~~maximum~~ limits, moreover,

if A & B ~~in the image~~ fall near to the extreme periphery of the circle

they become ill defined.

(4) It may be advisable, if (the camera if it be more than the usual height, to slightly tilt ~~the camera~~ it

in order to bring the fiducial points well into ~~the~~ its

field of view, but the back of the camera in all cases ~~slide~~ must be kept strictly vertical.

Calling the optical centres of the lenses in the 2 cameras N_1 & N_2 respectively

5) the height of N above the ground, that is to say the value of N_1M_1 is taken at 60 inches = 5 feet, chiefly

on account of ~~certain other~~ an important group of cases for further considerations in which only one

camera is needed, which will ... The height N_2M_2

does not affect the solution ~~is unimportant~~ & may be left undefined)

12/20
12
80
74
6

f 15r

of view of the camera ~~may be taken as~~ subtends fully 40°, (2) that the distance of M_1 & M_2 from AB & BC respectively ~~the~~ are fully 65 times the length of the equivalent focus of the lens, beyond which distance all objects remain sufficiently well in focus (3) that 45° is a convenient inclination of BC to ~~angle between~~ AB & BC, because ~~as~~ it admits of most of the points ~~most objects~~ on one side of a solid object being visible, for the most part ~~from~~ in both cameras; & at the same time it affords a large ~~yields an ample~~ parallax. Of course more than 2 cameras might be ~~were~~ worked simultaneously, ~~and serving~~ partly for [illegible] verifying results and partly for fixing a greater number of ~~showing~~ more points in the object but such cases as these ~~they~~ do not require consideration now.

Consequently with a full apertured portrait lens of 3 inches equivalent focus ~~diameter~~, the distance from M to AB would be at

and the
~~The~~ Photographs of ~~a~~ isolated point in space within the common field of view such as the light on wing of a flying bird ~~when~~ taken simultaneously by each 2 cameras will ~~contain in the yield 2~~ give pictures such as Fig 3 & 4. Fig 3 contains ~~the a~~ representative image of P. ~~both its together with that~~ of A & B here called for distinction ~~them respectively~~ p_1 a_1 b_1 and Fig 4 similarly contains p_2 a_2 b_2

From these ~~photographs of all the two~~ ~~three~~ coordinates ~~of~~ ~~x~~ y of P namely the x & y that lie in the plane of the map (It will be shown that two of the three) can be laid down on ~~the~~ map Fig ~~then~~ that the third coordinate Z ~~ap~~ or its vertical Z can then be determined from fig 12) in which the height of the camera NM is taken into account

f 16?

arranced to working simultaneously, & [illegible]

Let Fig 1 be a correct map of the installation of 2 cameras ~~the one above~~ M_1 & ~~the other at~~ above M_2 respectively, the height of at least one of the cameras fixed being also known ~~Fig 2 shows~~ ~~[illegible]~~ the position of three fiducial marks on the ground ~~[illegible]~~ two ~~simultaneous~~ photographs ~~such as Fig 3~~ are taken

of a point P (such as the wing tip of a flying bird) [illegible] (one) [illegible] M_1 shows the photo of P, called here P_1' &

~~Fig 3~~ includes ~~at the same time~~ the two fiducial points ~~[illegible]~~ viz: A & B

Fig 4 is that taken from M_2 & shows the photo of P here called P_2' & includes the two fiducial A points the B ~~&~~ C [illegible] Then, it is required

to express what is required or more particularly,

to find the position of P. ~~That is to say~~ if a perpendicular

be dropped from P meets the ground at Q, & if BA be prolonged ~~on south side and a point O be taken in it at~~ ~~a convenient but known distance, AO~~ as far as needful & taking A as the centre to serve as a centre of coordinates ~~(say such that OA = AB)~~ and

if ~~[illegible]~~ a line AX be drawn ~~from Q~~ at right angles to A,B ~~QB~~ from ~~produced beyond B if necessary & meets it at X~~ and prolonged when necessary, then,

it is required to find the 3 coordinates of P, viz AX = x, XQ = y along to it [illegible] QP = z.

The conditions that have been ~~to be~~ considered in arranging the installation in fig 1 are (1) that the effective width of the field

f.16v

Fig 2 is a sectional Elevation of Camera M_1 along a line from M_1 at ⊥ to AB

of 2 cameras arranged to work ~~[illegible]~~ as shown in plan (as a map) in Fig 1 & in one of its sections in Fig 2 [illegible]

Fig 1 is a map of the installation of ~~which the~~ whose [illegible] scale ~~is~~

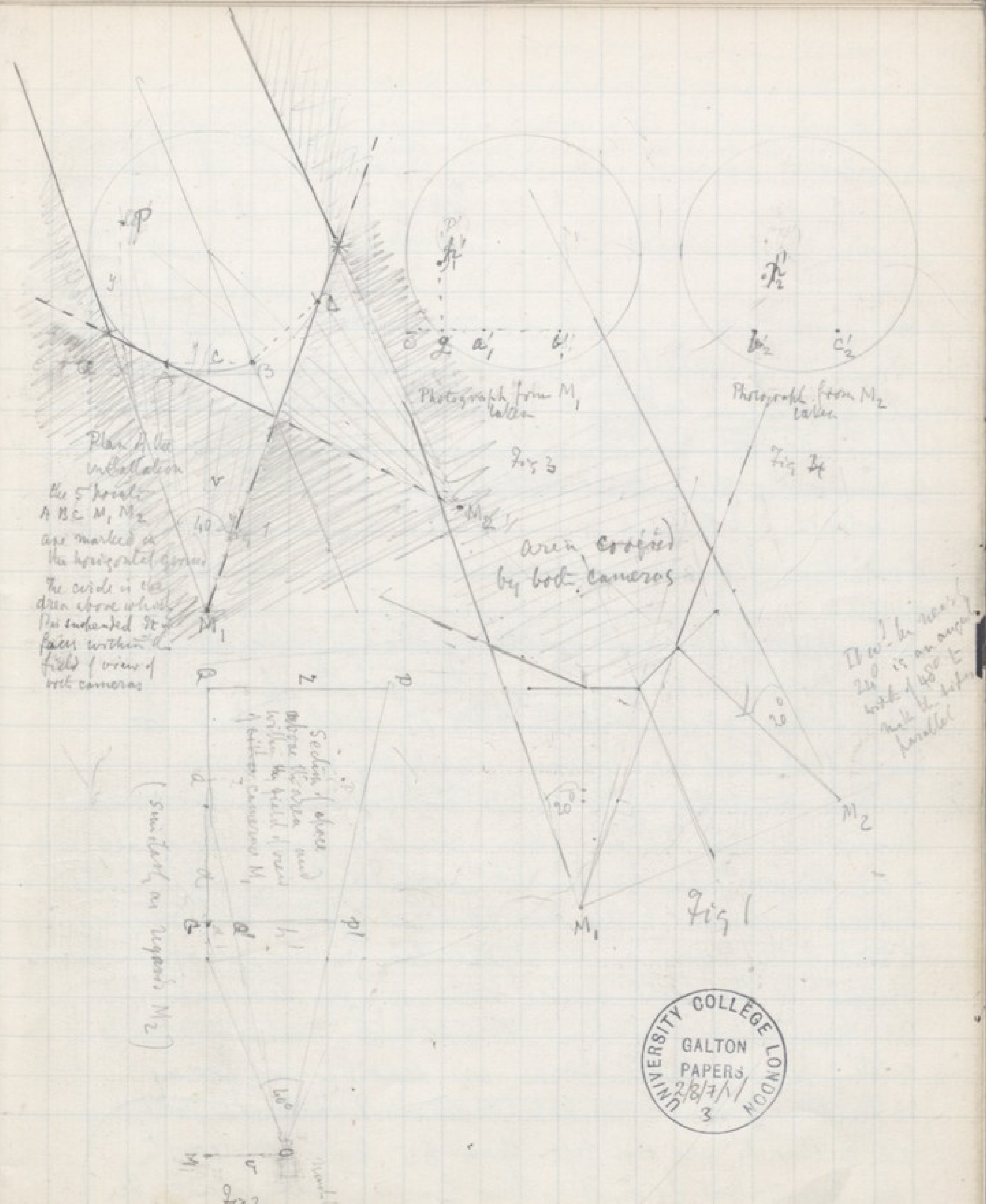
~~scale of which is~~ ~~supplied~~ given by the ~~known~~ graduation of ~~the~~ ~~length~~ of ~~AB~~ the distance ~~is~~ ~~sufficiently lengthened~~ ~~between A & B~~ AB or CD ~~which~~ ~~is~~ represents ~~a~~ ~~measured~~ ~~distance~~ known lengths

~~A camera~~ in the actual installation

in which AB may be graduated to give ~~a~~ ~~true~~ a the scale ~~of reduction~~ of inches or other unit.

The plan ~~It~~ contains 6 fiducial points made ~~by~~ by marks ~~by~~ on bricks or stones let into the ground. The optical centres of the cameras N_1, N_2 ~~stand~~ vertically above M_1 & M_2 and the height of at least one of them say $N_1 M_1$ is known

The lines connecting AB & CD serve as ~~are~~ base lines ~~of known lengths~~ to ~~the~~ the length of either of them say AB gives the scale of the map & it may be suitably graduated. ~~The~~ ~~proportion~~ the field of view common to the two cameras, ~~on both planes of the [illegible]~~ when the angles of ~~view~~ of the lenses is as represented in the map, is limited ~~shown~~ by the darkly dotted lines. The distances of M_1 from AB & M_2 from CD are such that all objects ~~within~~ beyond those lines are sensibly in focus at the same time, a condition which is attained when those distances are not less than 65 times the length of the equivalent focus of either lens. Consequently the reduction is great


P
p'
p'_1
p'_2
A
B
C
a'
b'
b'_2
c'_2
Photograph from M_1 taken
Fig 3
Photograph from M_2 taken
Fig 4
Plan of the installation
the 5 points A B C M_1 M_2 are marked on the horizontal ground
The circle is the area above which P is suspended so as to fall within the field of view of both cameras
40
M_1
M_2
area occupied by both cameras
20
20
It would be nearly 24° is an angle width of 40° to make the sides parallel
M_2
M_1
Fig 1
Q
Z
P
Section of space above the area and within the field of view of both cameras M_1
(similarly as regards M_2)
d
d
Q'
q'
P'
h'
40°
M_1
O
Fig 2

f. 1v

— 124" ... for h

— measured
hevised of h = 132

— 114" for i
calc — measure of i

$\frac{k}{2} = 21$ $a + \frac{k}{2} = 343$

Bronze Horse (Carousel)

$\frac{29.3 \times 100}{186} = 15.4$

p	$a = 487$ by calc. (322) $v = 56.7$ " " ; $O_1x_1 = 86.0$ — values of O_1g_1	values of p_1g_1	a as before $v = 55.0$; $O_2x_2 = 86.4$ — values of O_2g_2	$\frac{O_1g_1}{O_1x_1} \times 100 = O_1g_1 \times 117$	$\frac{O_2g_2}{O_2x_2} \times 100 = O_2g_2 \times 116$	$\frac{p_1g_1}{O_1x_1} \times 100 = p_1g_1 \times 117$	$a = 487$
a	67.7	14.0	71.1	79.2	82.5	16.4	$\frac{v \times 100}{O_1x_1} = 5.66$
b	70.3	9.2	55.0	82.3	63.8	10.8	$\frac{a \times 100}{O_1x_1} = 5.66$
c	70.3	1.9	# 55.1	82.3	(63.9) 53.3	02.2	$l = 86.0$
d	23.6	8.8	23.4	27.6	27.1	10.4	$l' = 73.1$
e	23.8	1.5	23.4	27.8	27.1	01.8	$K_a\lambda = 41.4$
f	60.0	22.5	55.5	70.2	64.4	26.3	$K'_a\lambda' = 8.5$
g	63.3	32.7	63.8	74.1	74.0	38.3	
h	53.3	49.8	52.0	62.4	60.3	58.3	$a \times \frac{100}{l} = 321$
i	42.2	40.8	39.0	49.4	45.2	47.7	
j	34.8	20.7	40.7	40.7	47.2	24.2	
k	28.4	15.3	32.4	33.2	37.6	17.9	

	X	Y	Z
a	83.0	41.05	11.7
b	86		10.-
c	83.5	8	0
d			8.1
e	27.0 (26)	9	0
f	71	28	22
g	75	16	27
h	63	24	58.7
i	49.5	14.5	47.5
j	39	24	27
k	32	31	13

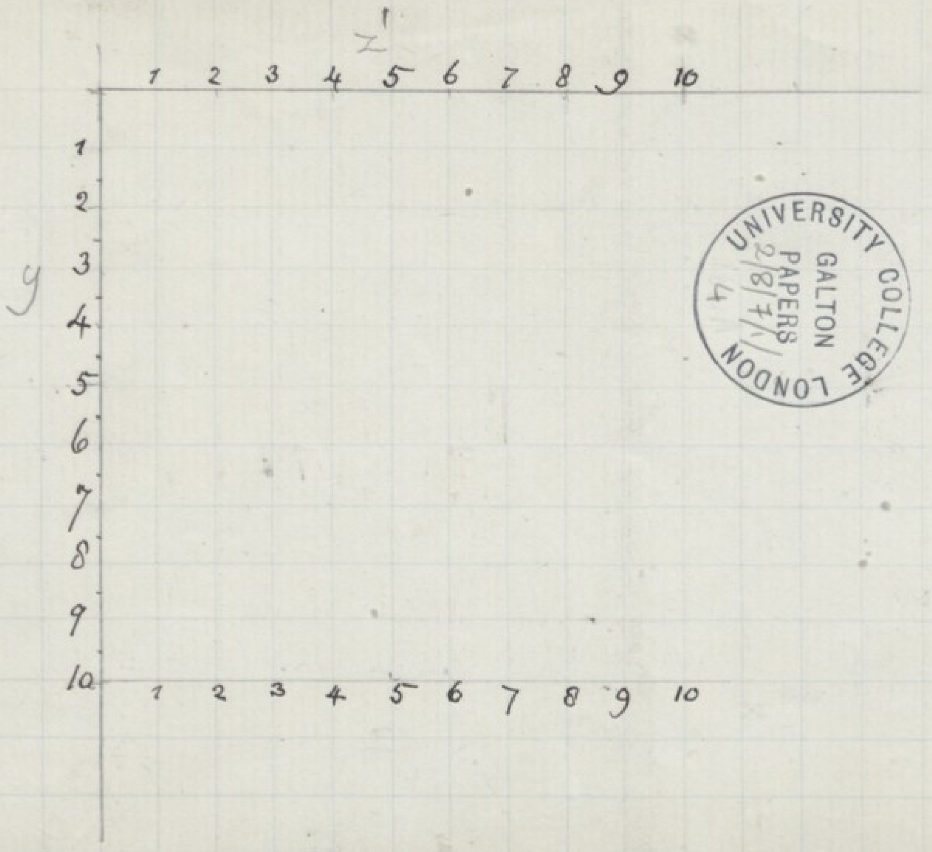
real value

b–d = 56.5 units and = $\frac{l}{100}$ =

$\frac{135}{58} = 2.41$

h = 58.7 — real height : 58.7 :: 135 cm : 56

real height = $\frac{58.7 \times 135}{56} = \frac{7866}{56} = 140$ cent.



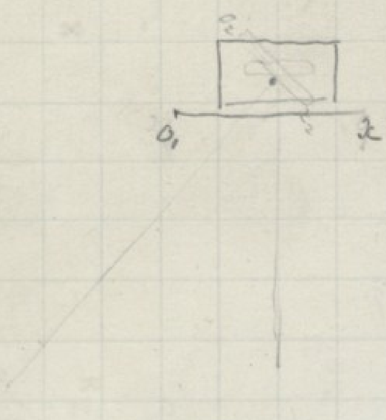
f.2

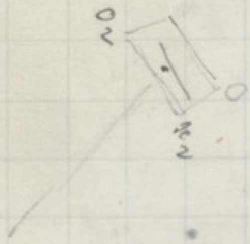
$a + l = 5'.14$

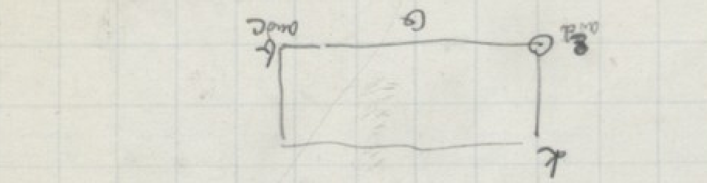
f. 3r

$26.0 \times 116 = 31.6$

Pictures in face







Plane of XY

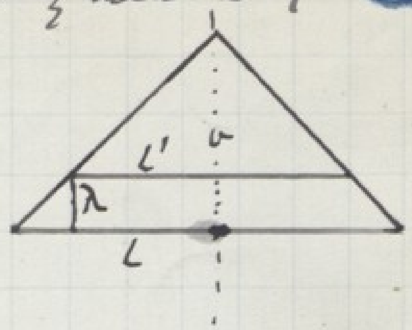
f.5

Another attempt

but the drawing board
arrangement was not as good
as might be – The squared paper was
of this sort only

March 11

Measurement of the installation by means of the fiducial points



Measured on photo

$OX_1 = 58$ mms $OX_2 = 70.8$

$$\left.\begin{array}{l} l = 58 \text{ mms} \\ l' = 44 \\ \lambda = 14 \end{array}\right\} l - l' = 14$$

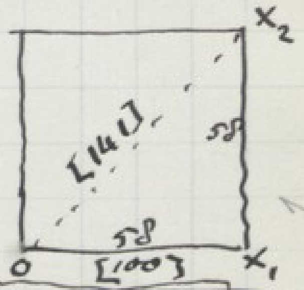
$a : a+l :: l' : l$ whence $a = l' \cdot \frac{l}{l-l'} = 44 \times 4{\cdot}14$

$v : v+\lambda :: l' : l$ ∴ $v = \lambda \cdot \frac{l}{l-l'} = 14 \times 4{\cdot}14$

$a = 182$ $v = 57.8$

$\frac{l}{2} = 29$

$a + \frac{l}{2} = 211$

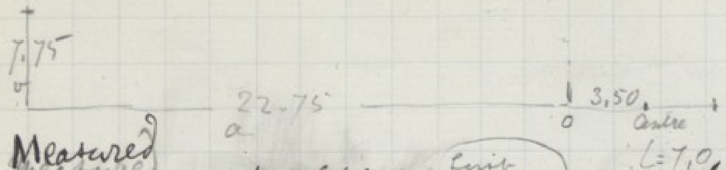


Take for scale of plan, $OX_1 = 100$ ~~division~~

	OX_1	= 100	scale L
$OX_2 = \sqrt{2} \times OX_1$	= ~~1.41~~ 141	= 141	diagonal OX_2
$58 : 100 :: 182 : A$	$A = \frac{18200}{58}$	= 314	= A
$:: 211 : A+L$	$A + \frac{L}{2} = \frac{21100}{58}$	= 362	= $A + \frac{1}{2}L$
$:: 57.8 : V$	$V = \frac{5780}{58}$	= 99	= V

f.7

Actual measures of installation (2)
compared with calculated



Measured

	divided by 7.08 (correct to about 1%)	first adopted after an error in scale	recalculated from photographs
l = 7.08 inches	0.998	1	1.00
a = 22.75	3.21	4.14	3.14
$\frac{1}{2}l$ = 3.50	0.50		0.50
$a+\frac{1}{2}l$ = 26.25	3.71	4.64	3.64
v = 7.75	1.10	1	1.00

In future use

L = 1.00
A = 3.21
$a+\frac{1}{2}l$ = 0.50
= ~~3.71~~
1.10

L = 1.00
A = 3.21
A + ½L = 3.71
V = 1.10

F.8 (3)

$OX_1 = 58$ $\quad$ $OX_2 = 70.8$

$\frac{1}{OX_1} = .0172$ $\quad$ $\frac{1}{OX_2} = .0141$

To convert any measure k in a photograph, to its corresponding measure K in the plan:—

(1) in the measures by camera M_1

$k_1 : K_1 :: ox_1 : OX_1$ $\qquad$ $K_1 = \frac{k(\text{in mms})}{ox_1(\text{in mms})} \times OX_1$ ~~when~~ $\left(= \frac{k}{ox_1} \times 100 \text{ plan units}\right)$

$= k(\text{in mms}) \times \frac{1}{ox_1(\text{in mms})} \times OX_1$ ~~in when~~

now let OX_1 be divided into 100 plan units . — $K_1 =$

or $K_1 = k_1 \frac{1}{ox_1(\text{in mms})} \times 100$ plan units

$= k_1 \times .0172 \times 100 = k_1 \times 1.72$ plan units

(2) in the measures by camera M_2

If the cameras were identical and ~~at~~ identically placed as regards OX_2, as they were as regards OX_1,

then as $OX_2 = \sqrt{2}\ OX_1$ and $ox_2 = \sqrt{2}.\ ox_1$ the above formula w^d^ hold good. But ~~these~~ conditions ($OX_2 = \sqrt{2}\,OX_1$) ~~are~~ is not wholly observed in the present case, because the distance of M_1 from OX_1 is $\underline{a}$, whereas that of M_2 from OX_2 is $\underline{a + \frac{1}{2}l}$

$k_2 : K_2 :: ox_2 : OX_2$ $\qquad$ where OX_2 is divided into 141 plan units

$K = \frac{k}{ox_2} \times 141$ plan units

or $K_2 = k_2 \frac{1}{ox_2(\text{in mms})} \times 141$ plan units

~~$= k \times 1.00$~~

$K_2 = k_2 \times .0141 \times 141 = k_2\, 1.9881 = k_2 \times 1.99$ plan units

In the photographs

y_1 means the perpendicular from any given point to Ox_1

δ_1 " distance from O to foot of above perpendicular

For	PG measured y_1	calculated $y_1 \times 1.72$	O_1G_1 measured δ_1	calculated $\delta_1 \times 1.72$	O_2G_2 measured δ_2	calculated $\delta_2 \times 1.99$
a	17.7	✓30.4	14.2	✓24.4	16.7	✓33.2
b	24.7	✓42.5	22.7	✓38.9	24.3	✓48.4
c	31.7	✓54.5	32.4	✓55.7	33.3	✓66.3
d	38.2	✓65.7	40.6	✓69.8	41.8	✓83.2
e	44.5	✓76.5	48.0	✓82.6	50.5	✓100.4
f	51.0	✓87.7	56.2	✓96.7	60.6	✓120.6
ha	54.0	✓92.9	47.7	✓82.0	49.7	✓98.9
hb	9.0	✓15.5	44.0	✓75.7	50.7	✓100.9

(see bottom of p 3 for data) $OX_1 = 7.08$ inches in reality **4**

From plan on drawing board where OX_1 = 100 units ~~each the width of $\frac{1}{10}$ division of this paper.~~ OX_1 = 2.70 inches. ~~In the object, the corresponding value is 7 inches, so the x, y, z results have to be multiplied by $\frac{7}{2.7}$ or 2.59 to bring them to true~~ measures in inches

measures on plan & sections in $\frac{1}{100}$ ths of OX_1

	X	Y	Z	X^2	Y^2	Z^2
a	25	~~72~~ 82	25	625	6724	625
b	34	70	39	1156	4900	1521
c	57	67	55	3249	4489	3025
d	73	57	67	5329	3248	4489
e	87	42	77	7569	1764	5929
f	104	32	93	10816	1024	8649
ha	86	48	97	7396	2304	9409
hb	78	38	0	6084	1444	0

distance between a and f (measured distance 7.7 inches)

	plan dimensions	squared
$\pm(x-x')$	86	7396
$\pm(y-y')$	40	1600
$\pm(z-z')$	68	4624
$\left(\frac{1}{10,000}\right)$		13620

Square root

~~.997 × OX~~ ~~2.59~~ ~~2.581296~~

~~.997~~ × 7.08 = ~~7.058~~

117

7

8.19

There has been an error in both plans 83 .46
a was erroneously calculated 4.14 instead of 3.14
$a + \frac{b}{2}$ 4.64 3.64

4' on incorrect data

In the plan 100 small graduations = 7.08 inches in the object
therefore as 100 : 7.08 inch :: n graduation : x inches
$x = n \times 0.0708$ inches

True equivalents of calculated

	x	y	z
A	1.34	5.31	1.84
B	2.62	5.10	2.90
C	3.89	4.60	3.96
D	4.96	4.25	4.74
E	6.09	3.19	5.66
F	7.22	2.34	6.51
H_a	5.80	3.12	6.86
H_b	5.52	2.61	

	Diff. A and F	squared	Square root
x	5.88	34.6	
y	2.97	8.8	
z	4.67	21.8	
		64.2	= 8.0
		Measured	7.7

	Diff B and E	squared	
x	3.47	12.0	
y	1.91	3.6	
z	2.76	7.6	
		23.2	4.8
		Measured	4.6

Another attempt with revised data and with the drawing board (5

	Calculated from photo measures copied from bottom of p. 3			in plan units, 100 = OX_1			× 0.708 to give true measures in inches		
	P_1G_1	O_1G_1	O_2G_2	Z	X	Y	Z	X	Y
A	30.4	24.4	33.2	25	17	72	1.8	1.2	5.1
B	42.5	38.9	48.4	39	36	71	2.7	2.5	5.0
C	54.5	55.7	66.3	56	56	66	4.0	4.0	4.7
D	65.7	69.8	83.2	67	74	58	4.7	5.2	4.1
E	76.5	82.6	100.4	81	86	46	5.7	6.1	3.3
F	87.7	96.7	120.6	92	102	32	6.5	7.2	2.3
H_a	92.9	82.0	98.9	98	84	46	6.9	5.9	3.3
H_b	15.5	75.7	100.9	0 don't intersect	77	37	2.6	5.5	2.6

For true distance between A & F

difference between	Squared
x' and x'' = 6.0	36.00
y' & y'' = 2.8	7.84
z' & z'' = 4.7	22.09
	65.93
Square root	= 8.1
By actual measure	7.7
Error	0.4

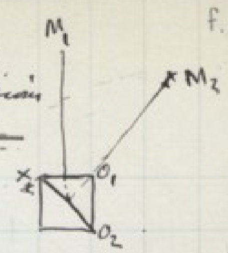
4 in 80 = 5 per cent

The squared paper on the board was of this kind which is not over well ruled. Henceforth it will be replaced by millimetre sectional paper

March 11/96

f. 13

Copy of repeated measures & plottings
3rd attempt with drawing board and squares like those.
on this paper length O_1X = 10 of ~~?~~ O_2X = 14.1 length of these divisions



in photo, O_1X = 57.7 mm | O_2X = 70.8 m.

In the object $XO_2 = 10$ inches $\therefore XO_1 = \frac{XO_2}{\sqrt{2}} = 7.09$

in the plan XO_1 = 10 of the divisions on this paper = 2.83

see next page

(I) length of perpendicular to O_1X

from	mms
A_1	17.7
B_1	24.7
C_1	31.7
D_1	38.2
E_1	44.5
F_1	51.0
Ha_1	54.0
Hb_1	90

(II) ~~to O_2X~~

from	mms
A	not wanted
B	
C	
D	
E	
F	
H_a	
H_b	

(III) Distance from O_1 to foot of perpendicular; (IV) Distance from O_2 to foot of perpendicular

from	(III)	from	(IV)	$\frac{III}{O_1X}$	$\frac{IV}{O_2X}$ O_2X divided into 100 parts	×1.41 141 parts	results in inches of x on plan: x	y	z	2nd attempt small squares at sides
A_1	14.2	A_2	16.7	24.7	23.5	33.1	19	75	26	27
B_1	22.7	B_2	24.3	39.4	34.2	48.2	37	72	41	40
C_1	32.4	C_2	33.3	56.3	46.9	66.1	53	65	56	56
D_1	40.6	D_2	41.8	70.6	58.9	83.0	70	60	67	67
E_1	48.0	E_2	50.5	83.5	71.2	100.3	86	45	80	80
F_1	56.2	F_2	60.6	97.7	85.4	120.4	102	33	92	89
Ha_1	47.7	Ha_2	49.7	77.7	70.0	98.7	82	44	97	-
Hb_1	44.0	Hb_2	50.7	76.6	71.4	100.6	78	37	34	-

full size scale measured true
100 : 7.08 = n : x

$x = n \frac{7.08}{100}$

$= n .708$

Repeated measures x all (For M_1, For M_2

			not wanted			$\frac{hg_1}{OX_1}$ sliding rule checked in with G curve (C)	not wanted
OX_1 · 57.7			OX_2	70.8			
length of perpendicular to OX_1							
from AG_a	17.7		AF_a	12.5		30.7	
BG_b	24.7	7.0	BF_b	17.7	5.2	42.9	
CG_c	31.7	7.0	CF_c	23.6	5.9	55.1	
DG_d	38.2	6.5	DF_d	29.4	5.8	66.4	
EG_e	44.5	6.3	EF_e	35.2	5.8	77.4	
FG_f	51.0	6.5	FF_f	41.0	6.8	88.7	
H_aG_{ha}	54.0		H_aF	46.8		93.9	
H_bG_{hb}	9.0		H_bF_{hb}	3.3		15.6	

[illegible]

from O to foot of perpendicular to OX_1		from OX_2		$\frac{og}{ox_1}$ 100.0 (A)	$\frac{of}{ox_2}$ 100.0	$\frac{of}{ox_2} \times 1.41$ 141 (B)	x	y	z
OX_1 57.7 $= \frac{1}{1.73}$		OX_2 70.8 $= \frac{1}{1.41}$							
for G_a A	14.2	A G_a	16.7	24.7	23.5	33.1	19	75	26
G_b B	22.7	B G_b	24.3	39.4	34.2	48.2	37	72	41
G_c C	32.4	C G_c	33.3	56.3	46.9	66.1	55	65	56
G_d D	40.6	D G_d	41.8	70.6	58.9	83.0	74	60	67
G_e E	48.0	E G_e	50.5	83.5	71.2	100.3	86	45	80
G_f F	56.2	F G_f	60.6	97.7	85.4	120.4	102	33	92
G_{ha} Ha	44.7	Ha G_{ha}	49.7	77.7	70.0	98.7	82	44	97
G_{hb} Hb	44.0	Hb G_{hb}	50.7	76.6	71.4	100.6	78	37	34

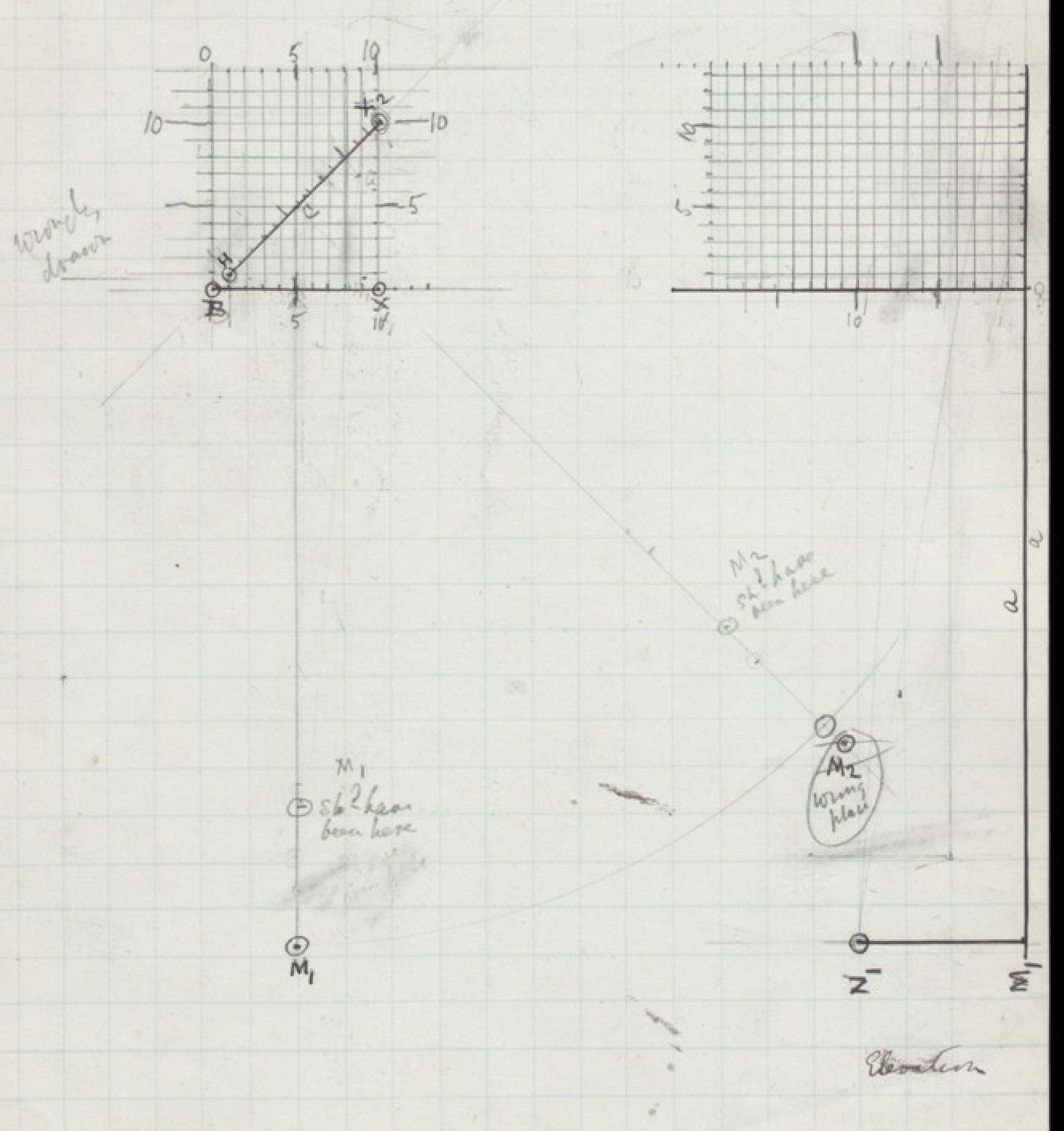
Here OX_2 is divided into 141 parts not into 100

16

$\frac{OG_f}{OX_2} \div \frac{16.7}{70.8} = 16.7 \times 1.41 = 23.5$

$= \frac{16.7}{57.7} = 28.9$

Faint Plan of installation: – distance between fiducial points in primary camera = 1 inch   in secondary = 1.41 inch   F.15



F 16

	bx_1	bg	hg	hx_2	hf	hf	$\frac{bg}{bx_1}$	$\frac{hg}{bx_1}$ ×	$\frac{hf}{hx_2}$	$\frac{hf}{hx_2} \times 1.41$	x ×	y	z
A	58	14.2	18.0	70.7	16.5	~~12.9~~	0.245	0.311	.234	.329	.20	.45	.27
B	,,	23.0	24.6		24.1	~~18.0~~	0.397	0.424	.341	.481	.38	.48	.31
C	,,	32.5	32.0		33.0	~~23.8~~	0.630	0.552	.467	.658	.55	.48	.50
D	,,	40.6	38.5		41.8	~~29.7~~	0.700	0.664	.592	.835	.72	.65	.60
E	,,	48.0	44.5		50.3	~~35.5~~	0.828	0.768	.712	1.003	.90	.70	.70
F		56.4	51.2		60.4	42.2	0.972	0.883	.855	1.205	1.05	.76	.85

2nd attempt at protractor

Repeated with larger plan on drawing board

	$\frac{bg}{bx_1}$	$\frac{hf}{hx_2} \times 1.41$	$\frac{hg}{bx_1}$	x	y	z	x	y	x	y		
A	2.5	3.3	3.1	20	45	25	20	75	26	83	27	
B	4.0	4.8	4.2	38	47	31	38	74	37	73	40	13
C	6.3	6.6	5.5	55	46	51	66	76	66	78	56	16
D	7.0	8.4	6.6	6.8	63	60	75	90	73	56	67	11
E	8.3	10.0	7.7	9.0	65	72	~~90~~	~~89~~	87	47	80	13
E	9.7	12.0	8.8	10.7	80	87	~~88~~	~~21~~	102	32	89	9

f. 17

Rough work — has been copied fair

Carousel Horse.

I

	$OX_1 = 86.0$		$OX_2 = 86.4$	OX_1 again
	values of (x) These are complements	values of (z)		values of x
a	18.3 ✓	14.0 ✓	71.1 ✓	67.7
b	15.7 ✓	9.2 ✓	55.0 ✓	70.3
c	15.7 ✓	1.9 ✓	−55.1 ✓	70.3
d	62.4 ✓	8.7 ✓	23.4 ✓	23.6
e	62.2 ✓	1.5 ✓	23.4 ✓	23.8
f	26.0 ✓	22.5 ✓	55.5 ✓	60.0
g	22.7 ✓	32.7 ✓	63.8 ✓	63.3
h	32.7 ✓	49.8 ✓	52.0 ✓	53.3
k	57.6 ✓	15.3 ✓	32.4 ✓	28.4
i	23.8 ✓	40.8 ✓	39.0 ✓	42.2
j	51.2 ✓	20.7 ✓	40.7 ✓	34.8

$l = 86.0$

$l' = 73.1$

$\lambda = 8.5$

$$a = \frac{ll'}{l-l'} = \frac{86 \times 73.1}{12.9} = \frac{6286.7}{12.9}$$

$$= 487$$

$$v = \frac{l\lambda}{l-l'} = \frac{86.0 \times 8.5}{12.9} = \frac{731}{12.9}$$

$$= 56.7$$

Bronze Horse

Slab on which it stands is 135 cm long, 70 wide, 20 thick
from photo 5 calculated = ~~56 29 wide 63~~

measures on photo I

$O_1 Z_1$ by measure = 86.0 mm

$O_2 Z_2$ " = 86.4 "

taking $O_1Z_1 = O_2Z_2 = 100$ then by calc^n

a becomes $278 \times \frac{100}{86.4} = 322$

v " $57 \times \frac{100}{86.4} = 66$

r = 54

$l = 86.0$

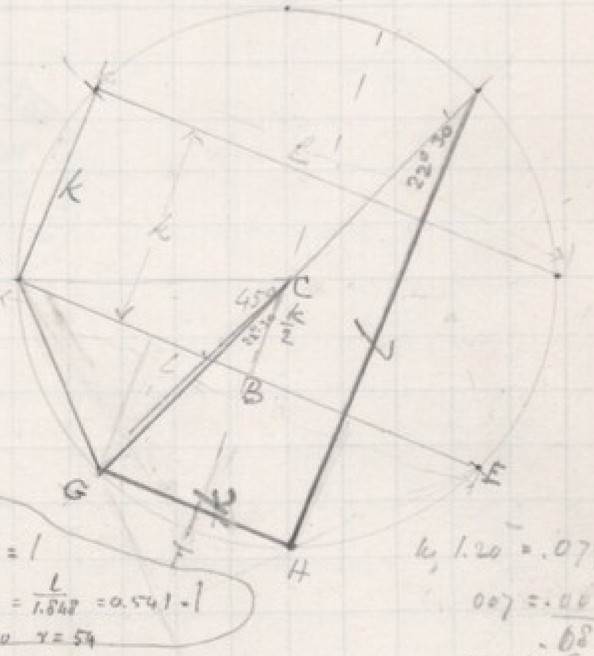
$l' = 73.1$ $\quad l - l' = 12.9$

$k (\text{or } \lambda) = 41.4$ $\quad \frac{l}{l-l'} = \frac{86.0}{12.9} = 6.72$

$k' (\text{or } \lambda') = 8.5$

$a = k \cdot \frac{l}{l-l'} = 41.4 \times 6.72$, $a = 278$

$v = k' \frac{l}{l-l'} = 8.5 \times 6.72$, $v = 57$



$CB = \frac{1}{2} \delta E \tan 22°.30'$

$\delta E = GH + 2\, \delta G \cdot \sin 45°$

$= GH\{1 + 2 \cdot \sin 45°\}$

$l = \delta E = GH \times 2.414$

$CB = GH \times 1.207 \times \tan 22.30$

$= GH \times 1.207 \times .414$

$CB = GH \times 0.50$

$2r \cdot \cos 22°30' = l$

$r = \frac{1}{2} \frac{l}{.924} = \frac{l}{1.848} = 0.541 \cdot l$

$l = 100$ $\quad r = 54$

k, 1.20 = .0792
007 = .0024
.0816
.414 = 9.6170
.6146 9.6986
.4993

$k = 2\,CB = GH \times 1.00 = 0.414 \times l$ $\quad \frac{1}{2}k = 0.202 \times l$

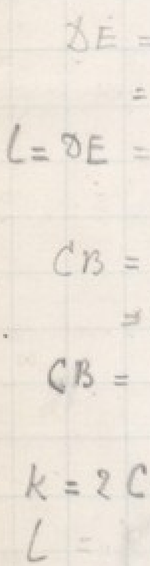
$l = \delta E = GH \times 2.414 = 2.414 \times k$

$\frac{k}{l} = \frac{1}{2.414} = .414$

More briefly

$k = l \tan 22°30 = l \times 0.4142$

$\frac{1}{2}k = l \times 0.2071$



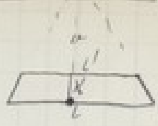
$\alpha : \alpha + k :: l' : l$, $\quad \alpha l = \alpha l' + k l'$ $\quad \alpha(l - l') = kl$ $\quad \alpha = k \frac{l}{l-l'}$

$\beta : \beta - k' :: l : l'$ $\quad \beta l' = \beta l - k' l$ $\quad \beta(l - l') = k' l$ $\quad \beta = k' \frac{l}{l-l'}$

Measurement of the installation by means of the Fiducial points

$l = 58$
$l' = 44$
$\lambda = 14$

$l - l' = 14$



$a : a + l :: l' : l$ whence $a = \frac{l l'}{l - l'}$ $= \frac{l}{l-l'} \times l'$

$v : v + \lambda' :: l' : l$ whence $v = \frac{l \lambda'}{l - l'}$ = height of camera $= \frac{l}{l-l'} \times \lambda'$

[illegible]

$a : a + \lambda :: l' : l$, $a(l - l') = \lambda l'$ $a = \frac{\lambda l'}{l - l'} = \lambda \cdot \frac{l'}{l-l'}$

$v : v + \lambda' :: l' : l$, $v(l-l') = l'\lambda'$ $v = \frac{\lambda' l'}{l - l'} = \lambda' \frac{l'}{l-l'}$

$\frac{l}{l - l'} = \frac{58}{14} = 4.14$

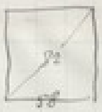
$a = 4.14 \times 58 = 240$ add $\frac{l}{2}$ to bring length to centre $= 269$

$v = 4.14 \times 14 = 58$

Primary camera { Take for ~~[illegible]~~ scale of plan $BB_1 = l = 1.0$ inch

~~[illegible]~~

$a = 240$ units in original
$a + \frac{l}{2} = 269$
$l = v = 58$



$\sqrt{2 \times 58^2} = \sqrt{2 \times 3364} = \sqrt{6728} = 82$ = diagonal of square field, in units

$58 : 10 :: 240 : x$ $x = \frac{240 \times 10}{58} = 41.4$ — a
$:: 269 : y$ $y = \frac{269 \times 10}{58} = 46.4$ — ~~[illegible]~~ $a + \frac{l}{2}$
$:: 82 : z$ $z = \frac{82 \times 10}{58} = 14.1$ — diagonal

$l = 1$ inch
$a = 4.14$ 3.14
$a + \frac{l}{2} = 4.64$ 3.64
$v = 1.0$ inch
diagonal $= 1.41$

~~[illegible]~~

Let j = interval between the two fiducial points in photo
J = — — — — — — in plan
d = any distance in photo
D = corresponding distance in plan

$D : d :: J : j$ $D = \frac{d}{j} J$

in photo of primary camera $J = 1$ inch
secondary " $J_2 = 1.41$ inch

Measures in scale of E with photo $\times J = 1$

Primary camera $j = 58$ $\frac{xy}{j} = \frac{48}{58}$ .828 inches
$x' = 44.5$ $\frac{x'}{j} = \frac{44.5}{58}$ .767 "
$xy = 48$

Secondary

$j_2 = 71$ $\frac{xy_2}{j_2} = \frac{50.5}{71} = .712 \times 1.41$ 1.00
$x_2' = 35$
$xy_2 = 50.5$ $\frac{x_2'}{j_2} = \frac{35}{71} = .493 \times 1.41$ 0.69

When $x = 3.3$ $y = 0.7$ $z = 0.6$

[illegible],

[illegible]

f. 1r 11

of the vertical plane on the "picture plane" ~~on which the perspective is projected~~ (and is therefore) common ~~both to the object & its perspective~~ ~~and the ground~~ ~~and~~ It bears and bears the scale according to all ~~of~~ which the measures are made ~~made computed~~ (well known laws of perspective). ~~By the~~

Every straight ~~objective~~ line in the plot or above ~~or in objects standing on it~~ is straight in the perspective, so every line in or above the plot, that is ~~really~~ ~~objective~~ parallel to AB (in perspective) is parallel to it also ~~in the perspective~~ & ~~every~~ every column or other line ~~that is objectively~~ perpendicular, on the plot, in the perspective, is perpendicular to AB ~~in the perspective~~

Lastly the point V at which the ~~lines~~ sides of the square, seen in perspective (AD', BE in fig 2) converge is the "vanishing point", therefore GV = C_1C which is the height of the eye, so the line of sight passes through C & V

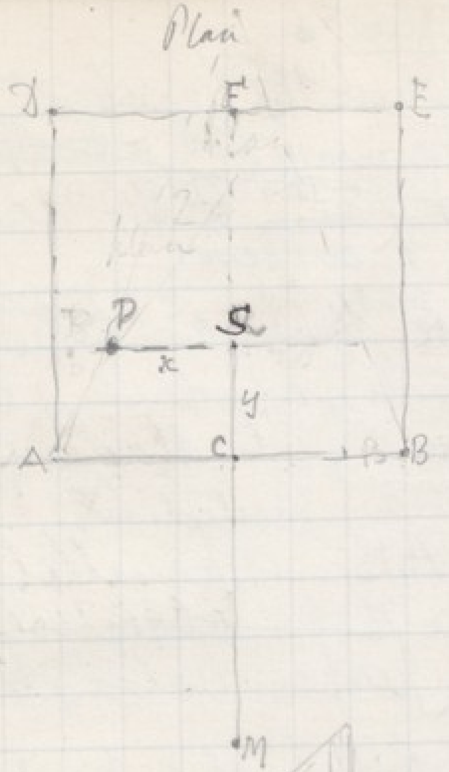
Our object is ~~We have now~~ to determine PQ ~~from the perspective~~ the objective height values GP', P'Q', ~~which may be following displaced to be painted on the picture plane~~ & from the ~~known values~~ data of transparent ~~height P'Q'. It may be done either by a draughtsman or by a calculator~~ other data already mentioned they are MP = $\frac{l'}{2}$ AG = a, C_1C = c = VG, AP' = d', P'Q' = h

$\frac{}{2}$ D'E' = L'. AM = $\frac{L'-l}{2}$ = $\frac{L'}{2}$ = k

for Q x y & z

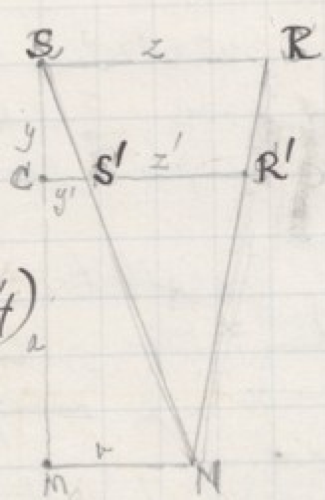
~~V is found~~

Plan

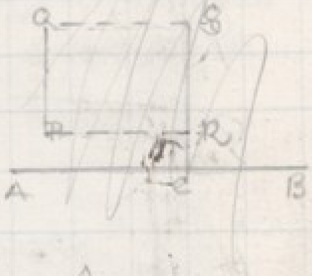


3)

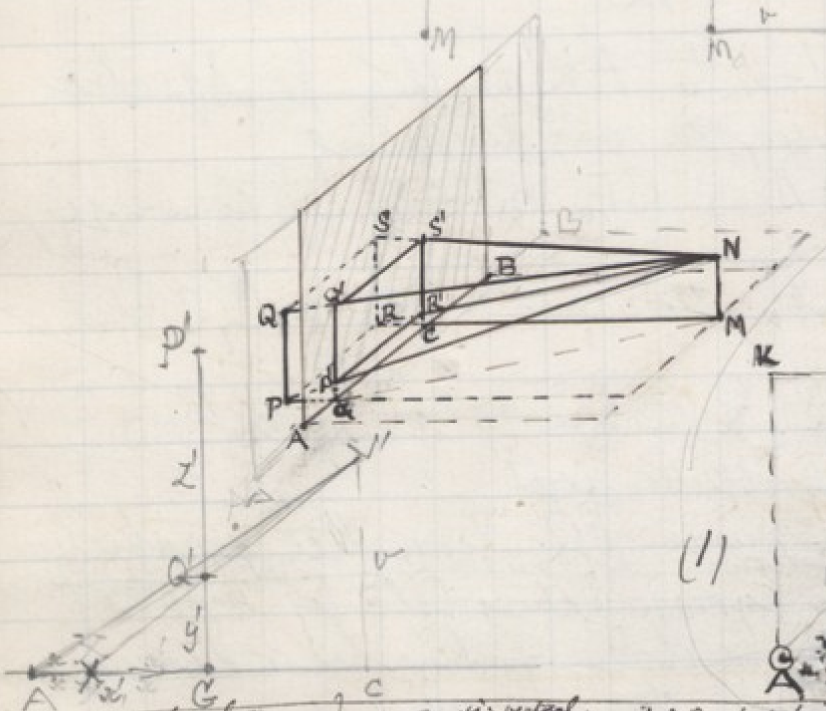
elevation in section



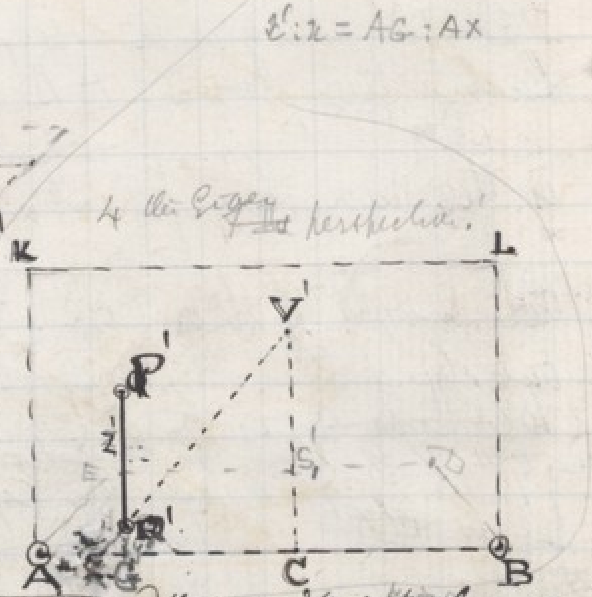
4)



$z' : z = AG : AX$



4 the ~~Ffs~~ perspective.



(1)

On a level ground, PQ is vertical a post, and AB a base line, ~~the ground being level~~

Given the 4 points A, B, P, Q, in ~~the~~ picture drawn as viewed from a certain point N, also the 3 following numerical constants measured in units ~~in terms~~ of AB ~~taken as unity~~: (1) NM = the Height of N the view point above the ground, (2) AC = the horizontal ~~the distance of AC from point C as measured~~ distance from A of the point M where a perpendicular from M drawn to AB meets ~~AB~~, (3) MC = the horizontal distance of the view point ~~camera~~ from AB. — Required the objective values of AX, XP, and PQ which are x, y, z the three coordinates of Q, ~~[illegible]~~ reckoned from A.

~~(1) $y/d : x' :: a+y : c$, whence $y = \frac{ay'}{c-y'}$~~

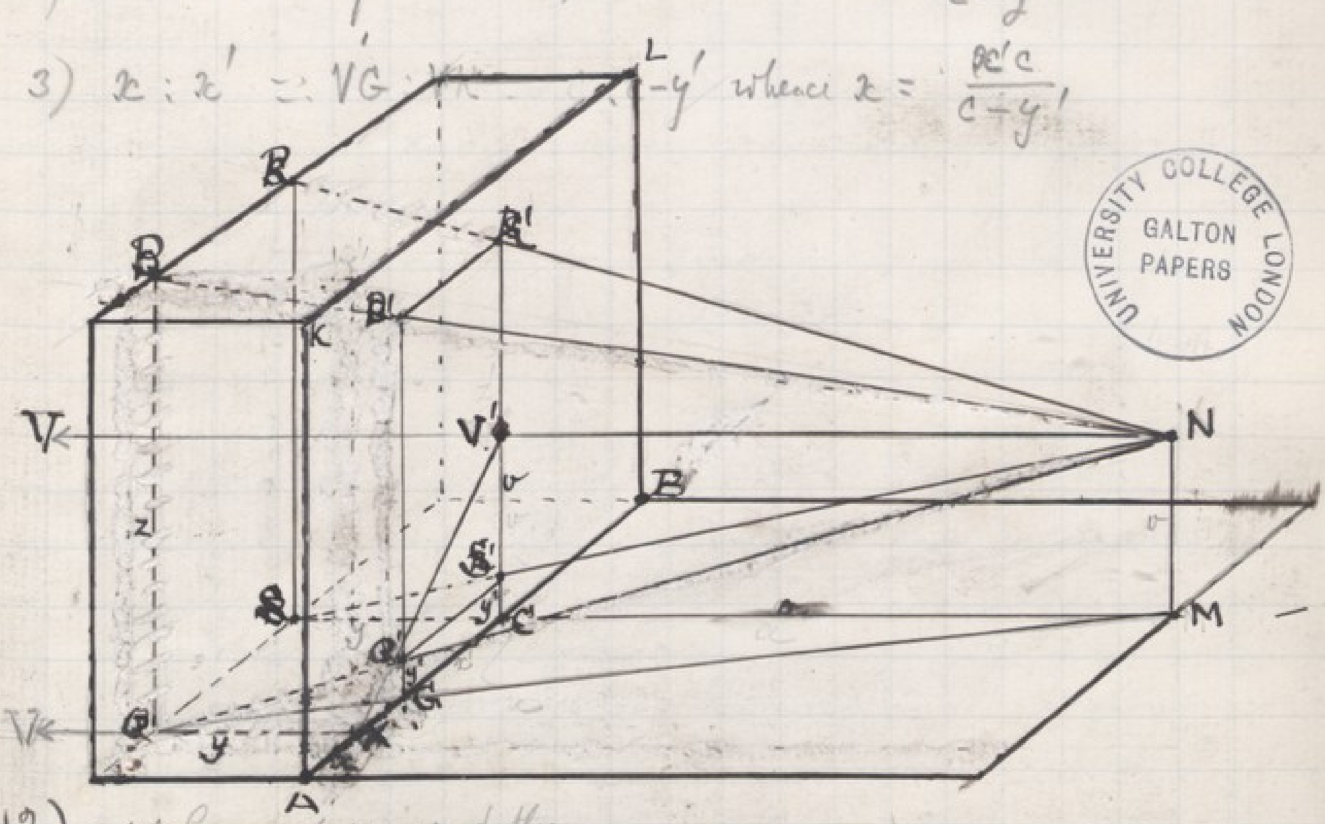
(2) $\frac{h}{z} : \frac{h}{z'} :: a+d : a$, whence $\frac{h}{z} = \frac{z'(a+y)}{a}$

$z = \frac{z'c}{c-y'}$

1). $y : y' :: y+a : c$, whence $y = \frac{ay'}{c-y'}$

2) $z : z' :: y+a : a$, whence $z = \frac{z'c}{c-y'}$

3) $x : x' :: VG$ ... $c-y'$ whence $x = \frac{x'c}{c-y'}$



(2) ~~A~~ General view of the "~~[illegible]~~"

ABLK is the "picture frame" that is a part of the picture plane within which bounds the picture of the objects lies

C is the centre of coordinates

$CX = z$, $CG = z'$
$QX = SC = y$, $GQ' = CS' = y'$

43 width of window
53 distance

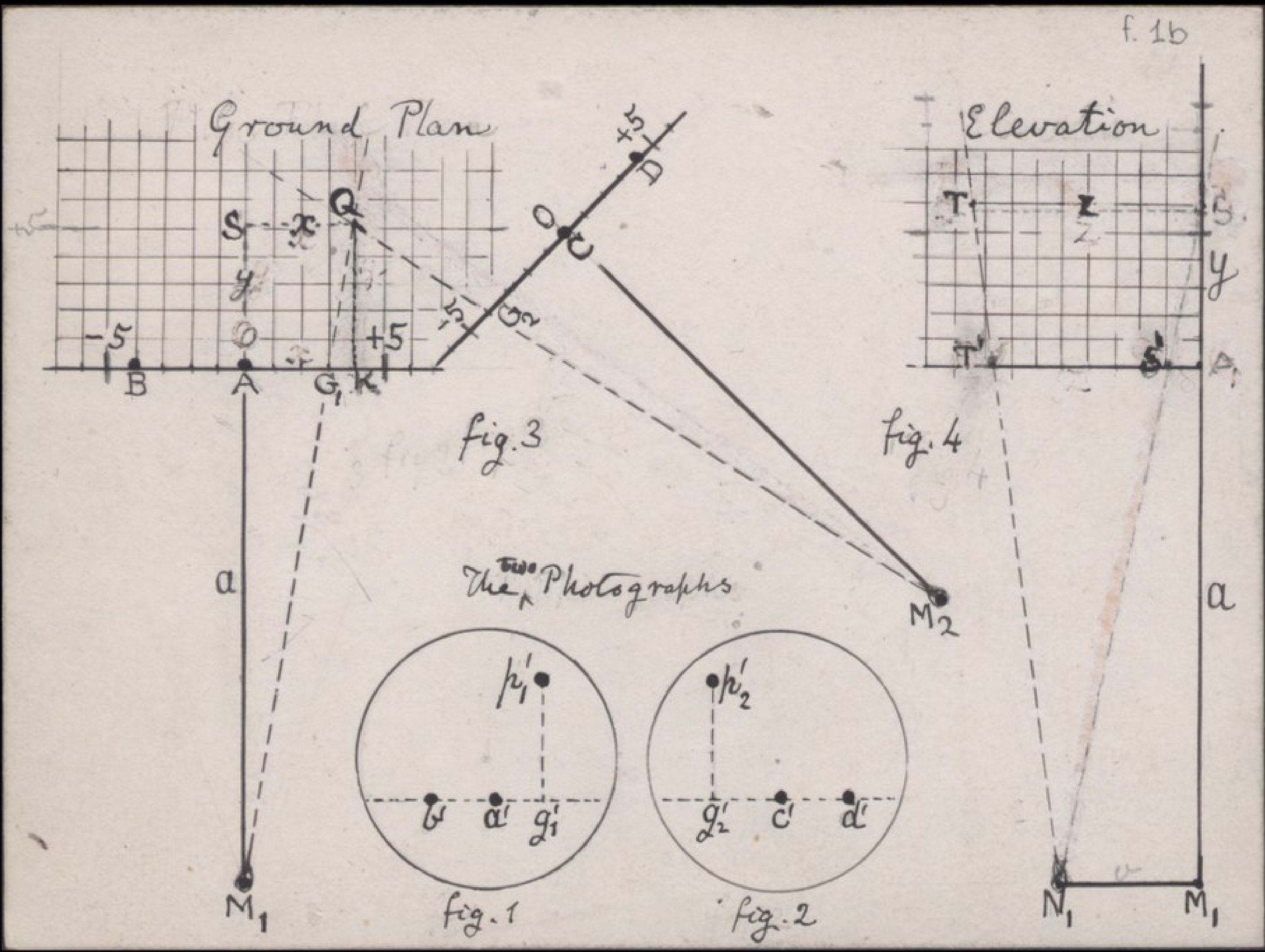
$\frac{43}{53} = 0.82 =$

$\sin \frac{1}{2}\theta = 0.41 = 22°15$
$\theta = 44°30$

Measurement of
Photographs

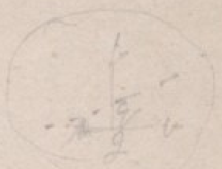
Rough draft — copy
sent to Nature March 4/96


SECOL THETFORD NORFOLK UK


f. 1b
Ground Plan
Elevation
The two Photographs
fig. 1
fig. 2
fig. 3
fig. 4
B
A
G1
K
-5
+5
S
Q
x
y
O
D
C
G2
M1
M2
a
p'1
b'
a'
g'1
p'2
g'2
c'
d'
T
Z
T'
S'
N1

f. 1c

fig 7



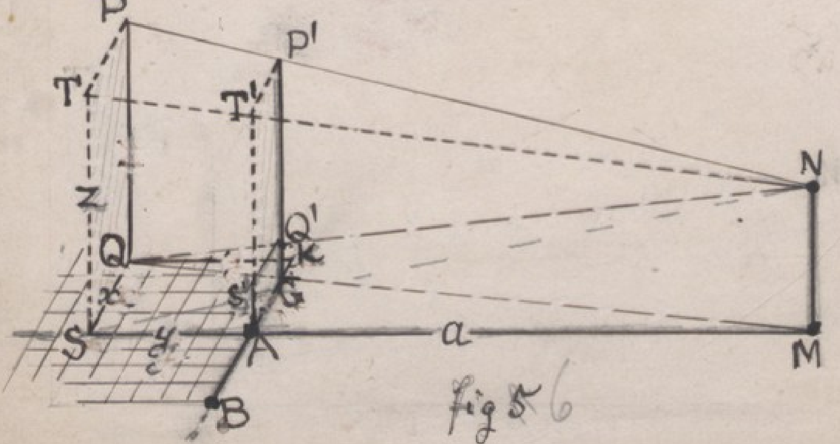
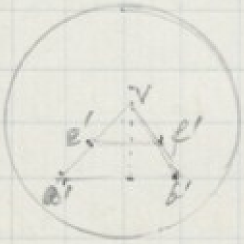


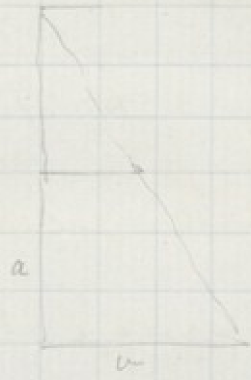
fig 5 6

If the distance of P from M does not differ much from a then y is small & the foreshortening $\frac{y'}{y}$ becomes approximately $\frac{v}{a}$ or in this case $\frac{60}{200} = 1 : 3\frac{2}{3}$, or say $1:4$. It is easy to apply the general rules that have been laid down so as to arrange the most convenient installation for any particular case. If the camera should have to be tilted forwards in order that $a'b'$ may occupy a convenient place in the picture, the back place must be kept strictly vertical.

It is worth while to consider how to arrange additional fiducial points so that a photograph of the vacant ground, taken from M shall verify the various measures made of it. Let E F be

f. 2v





" 17 "

The art of making ~~3~~ perspective drawings ~~from the elevation & front view~~ of ~~a real~~ real objects is well known; ~~but~~ in this paper I ~~purpose~~ propose to direct attention to the converse art of obtaining the measurements of ~~a~~ real objects ~~from~~ ~~their photographs in perspective~~ ~~views of it~~ ~~showing it~~ (perspectives of them obtained in the form of photographs taken in perspective, ~~has not been practised or even noticed~~ There is ~~no other~~ ~~It is the only method of obtaining correct~~ measurements ~~of the positions of objects~~ ~~of moving objects such as the~~

The extraordinary powers given to photography by the ~~processes~~ accuracy of lenses and the ... of films ~~to the process of~~ of rapid ~~photography~~, of seizing great detail in the momentary positions of a multitude of objects, offer a wide field to the use of the method about to be explained.

I myself was led to think about it ~~make the inquiry~~ by the difficulty of obtaining measures of thoroughbred horses

f.4 16

which would ~~be very valuable~~ be some for ~~inquiries~~ studies in heredity, ~~but which are~~ are not due to the fact that they whose measurement is not only difficult but ~~seem~~ also dangerous, ~~to make~~ ~~in such~~ being as ~~they~~ usually so sensitive & irritable (and of the vicious) ~~as they are~~ often and very ~~so~~ sudden & swift & uncertain in their ~~violent~~ movements

Two processes will now be described, in the first of these (~~two~~ ~~are used~~ to be employed; this process is of universal application, ~~and~~ requiring two cameras working simultaneously), the ~~other~~ second ~~which~~ & is applicable to a limited but still a considerable number of cases, including certain measurements of horses & requires only one camera. In ~~either of the two case~~ both cases the cameras are fixed ~~at some distance~~ situated at such a distance from the ~~area where~~ place to which the animal or other object is to stand, that ~~he will~~ no probable uncertainty in its error in position will sensibly affect the focus, & Lastly certain ~~...~~ fiducial

1c

they may be inconspicuous and
Marks have to be made on the ground; such
as ~~might~~ could be chipped ~~at~~ (and painted) on bricks
or paving stones let flush with its surface, or
Marks of the size of a penny are ~~sufficiently~~ almost large
enough for the purpose

f. 5

f.6 1

First process

The ~~area~~ ground or area ~~where~~ on which the photography is to take place is supposed to be hard & level, and to contain six fiducial marks ~~whose distances~~ whose relative positions have been carefully determined & marked. They are shown in the ground plan Fig 1 as a, b, c, d, M, M_2. The optical centres of two cameras N_1 N_2 which work simultaneously are placed, at known heights N_1M_1 N_2M_2 above M_1 M_2 respectively. This completes the installation. Two supplementary marks placed one on the opposite side of a & b and the other on the opposite side of c & d and at equal distance from them, would be convenient.

The ground plan fig 1 is drawn to scale, the good actions of crossed lines by ~~the~~ intersection above a b & c d, coincide with the lines above AB. The

The plan should be ~~drawn to a~~ ~~large~~ say such as would ~~on a good size~~ ~~scale~~ say such ~~that as it~~ fit the ~~to allow of free~~ cover an ordinary drawing board. The Elevation fig 2 is on the same scale as the plan, its scale here ~~then~~ expressed by the divisions above ~~PQ~~ crossed lines above a S above ~~PQ~~. The ~~dotted~~ broken lines ~~are~~ represent moveable strings each with a loop at one end to slip over a pin & the other free; when stretched they can be held in any desired position by pulleys & weights on the ends. One of these threads in fig 1 slips over a pin at M_1 and the another over a pin at M_2 & two of these are slipped over a pin at N_1. In fig 2 the loops of 2 threads ... the same.

The dotted line TS ~~is not a string but~~ shows the direction merely of ~~lines~~ to be followed by the eye in the particular case to which the fig 2 ~~should~~ refers

P is an isolated point in space, in view of both

~~or~~ for the pre
the cameras Q ~~either~~ ~~unknown~~ point on the area
its position is for the present quite indeterminate
that lies perpendicularly beneath P;. ~~unknown~~ ℞ (in fig

from which to P namely,
3) is the centre ~~whence~~ the 3 coordinates x y z

are to be and plotted
~~of P have to be determined~~ x) x & y ~~are~~ lying in the plane

Ground
of the ~~area~~ area ~~x~~ x coinciding with a line drawn through
Thus in fig 2 ~~to that~~ x any y are equal to respectively
AB, ~~they are~~ ℞K and KQ ~~respectively~~; z is

fig 3 Consequently only a point in the ~~plan~~, it will be seen to be identical with ST =)
perpendicular to the Ground ~~area~~ and identical with Q P fig 4

two
The photographs ~~that contain all necessary the data for~~

AP
~~determining the x y & z~~ are shown in figs 1 & 2

the first being taken by the camera M_2 the second
(The scale of ~~them~~ photographs is immaterial & need not be determined
by the camera M_2.) ~~They~~ Each ~~of them~~ shews a ~~position~~ perspective picture

of the 5 (or of 3 if there are 7 of them) other view of P, & that of ℞ & B
of P and of 2 fiducial points. Fig 1 gives p_1, here noted as a & b
(another view of P & of C & ℞ here noted as)
in figs 1 & 2
fig 2 gives p_2 c and d. The dotted lines do not appear
(are lines of operation to be
~~in the photograph, they are~~ are drawn on ~~the~~ ~~face or better~~
on the back of the photographs guided by made with a fine needle ~~fine~~ pinch holes through the ~~paper~~ made at the above mentioned points

(of ~~finding~~ determining the 3 coordinates x y z):

The process ~~will be described first~~ is as follows now, the rationale of ~~it~~ later

The first object is to find $\frac{AG}{ag}$, ~~CF~~ & $\frac{CF}{cf}$, & (then) the intersection of the strings stretched from N_1 & M_2 through G_2 & F_2 respectively determines ~~fixes~~ Q, whose x & y, (viz QK, and QS = KA) are ~~shown~~ by ~~off~~ (of the crossed lines) ~~at once~~ read off at once by their means

where ~~was~~ $AG = AB \times \frac{ag_1}{ab}$ $\quad CF_2 = CD \times \frac{cf_2}{cd}$

~~Note~~ ~~A~~ perpendicular being dropped (in fig 3) from p_1 to ab produced, ~~which~~ gives g_{11} ~~and~~ then ab & ag being measured, having regard to their signs, the value of $\frac{ag_1}{ab}$ is obtained, by ~~this may be done by~~ either ordinary division or more easily by using Crelle's tables or by a sliding rule

Similarly as regards ~~fig 2.~~ ~~fcd~~. G & F ~~G, & F~~ being thus fixed

~~Now turning to fig 2~~ Fig 4 shows how the value of yz first obtained, is ~~may be~~ utilised in conjunction ~~together~~ with that of pg ~~to draw~~ ~~$\frac{aq}{}$~~ ~~to be utilised~~ in order to determine z (which will show ... = ST)

Lay down AS(=y) from fig 3, ~~down~~ and on the perpendicular at a lay down t such that
$at = ab \frac{pg}{ab}$ Stretch one string from N_1 through t; its intersection with the perpendicular
at S gives T, and ST = QP = z can be read off at once. ~~The intersection of N_1S with at determines~~
(The other line N_1S_1 is not wanted now, but for the second process)

~~in the perpendicular from G_1~~

~~Lay down P' such that $G_1 P_1 = AB \frac{g_1 p_1}{ab}$~~

~~then stretch the~~ and the other thread from N_1 ~~so as to~~

pass through P', its intersection with the perpendicular from Q ~~gives~~ determines P ; whence the value of $Z = QP$ is read off at once.

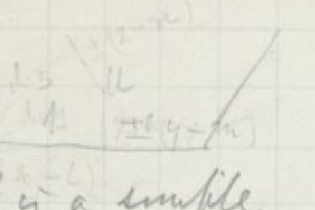
Thus the values of x y & Z for the point P are determined with much facility

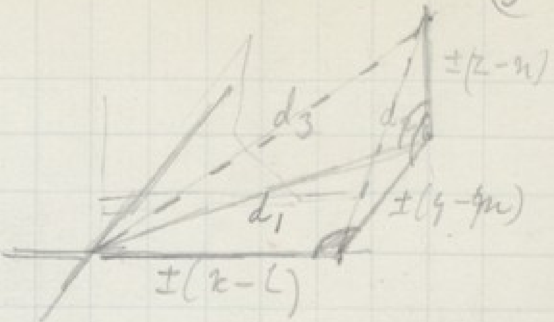
Let us now suppose that a second point U appears in the photographs (P might have been the tip of one wing of a flying bird & U that of the other) & that after its coordinates have been determined in the way just described, it desired to find the distance ~~(1) the distance in plan~~ between P & U (1) in the ground plan that is the plane of ~~XY~~, ~~(2) the distance in elevation~~ ~~side~~ that is the plane XZ, (3) in frontal view that is the plane YZ and (4) the actual distance between P & U

insert in next page ~~Let l m n be the 3 coordinates of U, d, 3~~

let l m n be the differences between the ~~two~~ values for P & U of x, y & z respectively

then the distances in question are (1) $\sqrt{\frac{x^2+y^2}{l^2+m^2}}$; (2) $\sqrt{\frac{x^2+z^2}{l^2+n^2}}$ (3) $\sqrt{\frac{y^2+z^2}{m^2+n^2}}$ and (4) $\sqrt{\frac{x^2+y^2+z^2}{l^2+m^2+n^2}}$





all this is a simple
~~that~~ is ~~merely an~~ affair of right angled triangles

fig 6

is shown in the ~~perspective~~ view of the arrangement
fig 6, where however the right angles ~~are distorted~~, the
~~angles~~ which are distinguished by small curved strokes ~~which~~
which are distorted & made ~~are~~ oblique in the perspective ~~fig really right angles~~ fig 6

It wd be tedious & is unnecessary to describe this in further
detail

It would be more tedious & is probably almost as unnecessary to describe in much detail the 2nd stage of the process just described which can be read off as it were from fig 5 ...
~~Neither is it unnecessary to describe~~ explain in detail why
~~which~~ I will be touched upon very briefly
~~a perpendicular in fig 1 & 2 from p1 to ab produced~~ a point at
~~determines a point that has the qualities of G in~~
~~fig 3. These matters of the difficulty~~ of understanding simple problems
~~which are by the eye~~ ~~follows obviously from the diagrams when these are well understood~~
To arrive at what is intended to be conveyed by the lines in a perspective sketch of any position
is caused by basic explanation or explaining by means of
geometry ~~from the necessity of describing perspectives~~
is usually quite beyond the part of the difficulty in understanding the problem drawing
which the eye cannot easily interpret

~~In fig 6 are contained both fig 3 & 4. $M_1 a S$, & ba, ap~~
are $M_1 aS$ and ba are given by construction

Now as regards the rational of the process already described.

Fig 6 represents a general view of the installation & optical lines, including what has already been shown in figs 3 & 4, and more besides. $a t p g$ is part of the "picture plane" as it is called in descriptions of perspective. It is a vertical plane, intersecting the horizontal one along the line of ab produced, the intersection with which of lines to N_1 from every point in the object produces the perspective picture of that object as viewed from N_1, the photograph is merely a reduction of ~~the~~ part of the picture plane, its internal proportions are the same and any measure in this one, r, can be reduced to that in the other r by the means of the relation r : r :: ab : ab. So the photograph may be left out of the question for the present, & attention confined to the perspective on the picture plane and the objects. As the same point ~~may appear~~ then appear under two aspects, and ~~indeed~~ under 3 when the photograph has to be mentioned the practice is adopted throughout of using Capital letters as P. Q when it is in the object, plain roman letters when in the picture plane, as p q, and italics when in the photograph as *p q*. Points in the line where the picture plane cuts the horizontal are common to both ~~& might be~~ but in this ~~method~~ nomenclature they are considered to belong to the picture plane.

We have in ~~the~~ fig 6, ab & the line through them, also $M_1 aS$ perpendicular to ab, given by the installation, and we have the point p given by means of the photograph & that is all, the rest of the figure is derivative. Thus $N_1 p$ produced passes through P, and the vertical plane through this line passes through M_1 and Q and intersects the picture plane & the ground at g. Consequently pg is perpendicular to abg and a horizontal line from M_1 through g, ~~or from~~ passes through Q, ~~but~~ (when seen in plan, M_1 is the projection of N_1), ~~therefore~~

~~a line~~ This is the property of g' that was utilised in fig 3 for finding Q, by the intersection of two threads ~~through~~ ~~[illegible]~~ stretched respectively from M_1 & M_2 through g' & f., whence $Qk = y$ $ka = x$. The position of P is at the intersection of $N_1 p$ with the perpendicular from Q. But this position cannot be derived directly by plotting either in plan or profile, so the various parallels are drawn as shown in the figure whereby $AS = Qk = y$ and $QS = ka = x$. These are the points shown in fig 4. There is yet another line in fig 6 from N_1 to Q cutting the picture plane at q. This point ~~[illegible]~~ is not wanted for the first process but will be used in the second but may be mentioned now and done with ~~[illegible]~~ $as = gq$ = the projection of the horizontal distance y on the vertical picture plane.

If the reader finds himself puzzled by the numerous lines and ~~[illegible]~~ ~~intersecting lines~~ planes in the diagram, which he well may be, it is strongly advised that he should roughly make a little model. I did so for myself, with lucifer matches stuck into gimlet holes & connected with thread., A comb ~~between~~ whose teeth the threads passed, ~~[illegible]~~ served as the picture plane. and ~~it~~ cleared the ideas at once. ~~[illegible]~~ By far the greater part of the puzzle caused by problems in over solid geometry in printed books is due, not to any inherent difficulty, but to ~~the unforeseeable troubles due~~ the necessity ~~to representing~~ to the confusion caused by ~~the~~ attempt to represent objects of 3 dimensions by a perspective of 2.

Second process

Thus far we have been considering engaged in determining the position of an isolated point & have found the necessity of two cameras ~~to be necessary~~ in order to determine Q, but there is a considerable class of cases in which Q is ~~shown~~ directly ~~such as~~ the vertical ~~post in the ground, or the edge of a building; in which~~ where and others in which its position may be inferred; ~~and~~ in these ~~cases~~ only one camera is needed to determine the 3 coordinates. Q is given directly by the base of a vertical post whose top is P, or by the foot of the edge of a building. Q is to be inferred for points along the belly or back ~~in the case~~ of a standing horse because a vertical plane lengthways through the spine & mid belly of the animal intersects the ground in a line drawn between its feet

That line is easily found by bisecting the interval between ~~corrpt~~ a pair of symmetrically disposed points which are rarely more than one hoof's breadth say long inches apart on the horses fore feet ; ~~and again~~ on his hind feet, similarly in respect to & joining the bisections. A vertical from the point along the spine ~~that~~ whose ~~position~~ coordinates have to be measured ~~intersects~~ intersects the above line at Q

In fig 6 let ww be the line in question. ~~Let fall~~ Drop a perpendicular from p to a b cutting it in g & ww in q. Then ~~(fig 4) $G_1 P' = AB \frac{gp'}{ab}$~~

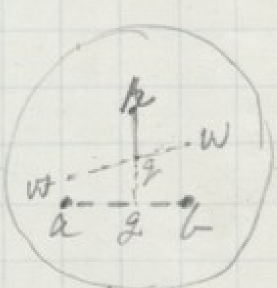


fig 6

& $GQ' = AB \frac{gq}{ab}$ and as already said, Stretch the threads from N_1 to Q' and the place where its prolongation cuts MG produced is Q. ~~Also where another thread $N_1 P'$ produced cuts the perpendicular at Q is P, Q being determined~~ The rest is as before

AX.x is found as before in fig 3.

It will be observed that unless the ~~angle~~
height of NM is considerable in respect to MG ~~or~~, the
distance of the camera from AB, this method of
determining ~~x~~ y is not precise ~~trustworthy~~. The proportions of the
installation that I have tried & that works well are
Equiv: focus of portrait lens 2.76 inches aperture 1.1 inch width of field of view over 40° MB = 16 feet 194 200 inches
that is ever about 65 times the focal length of the lens causing a corresponding reduction of scale
NM = 60 inches. The camera had to be somewhat
tilted in order to bring AB in a convenient position
in the field of view the focussing screen being of
course kept vertical. With a lens of longer focus ~~lens~~
NM would have to be proportionately higher
which is not only inconvenient to the operator but
ceases to give a fair broadside view of the object

The distance as above is I think unnecessarily great, though
it has the advantage that
~~for~~ all objects ~~at a~~ beyond AB are sensibly in the same focus
~~in because~~ In some of the beautiful photographs now made of

race horses the reduction is considerably less apparently about 1 in 25, ~~which~~ and the foreshortening of the foreground is ~~such as~~ moderate is ~~also~~ moderate such as w^d well admit of the application of this method for determining y. ~~On that~~

~~Considering~~ the service to the study of ~~heredity~~ inherited characteristics & ~~the art~~ of form ~~of good breeding~~ that ~~might~~ would be afforded by ~~photographs taken~~ of animals ~~under even~~ by even a single photograph showing two fiducial marks ~~such as the~~ ~~it seems~~ it deserves the consideration of authorities ~~consideration~~ whether facilities ~~should~~ might ~~not be given~~ at all shows of pedigree stock ~~to obtain~~ where the prize animals sh^d as a matter of course be photographed ~~the~~ exhibitors ~~of animals~~ of the other animals & where ~~the~~ of the ~~animals they send~~ might obtain ~~such~~ photographs at ~~small~~ reasonable cost ~~made with~~ a properly arranged installation should not be set up.

f. 16v 11

599 (Left vacant for the present)

.1

.2

g g g

g g g

.3

p p p

q

.4

62
23

.5

Q
Q

k k

.6

.7

.8

.9

f. 17a

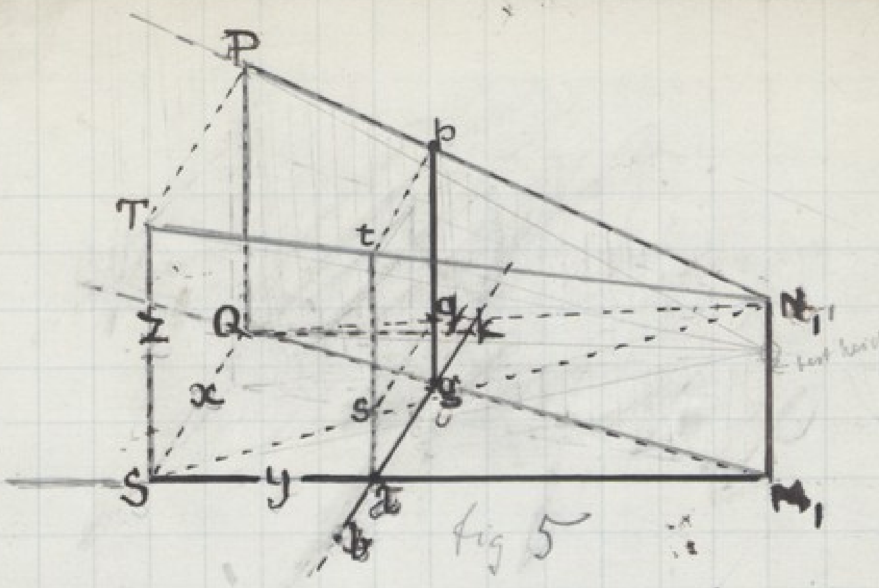


fig 5

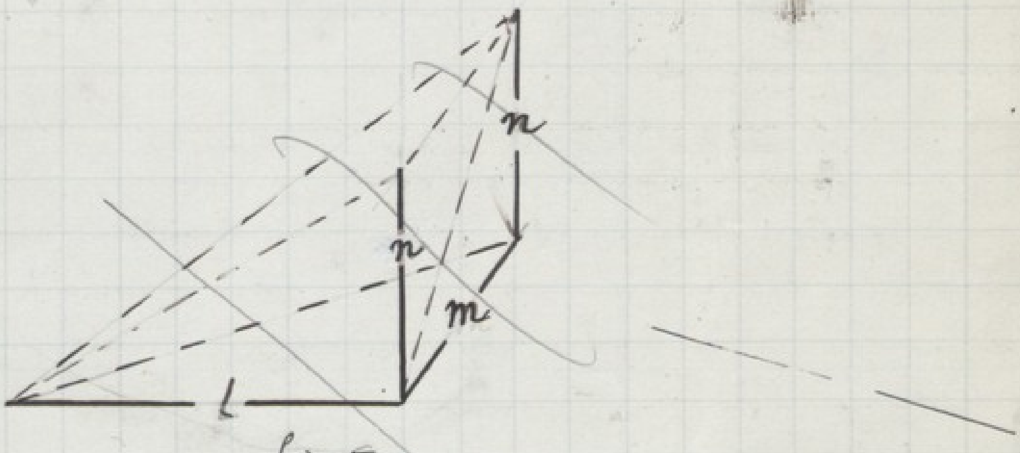
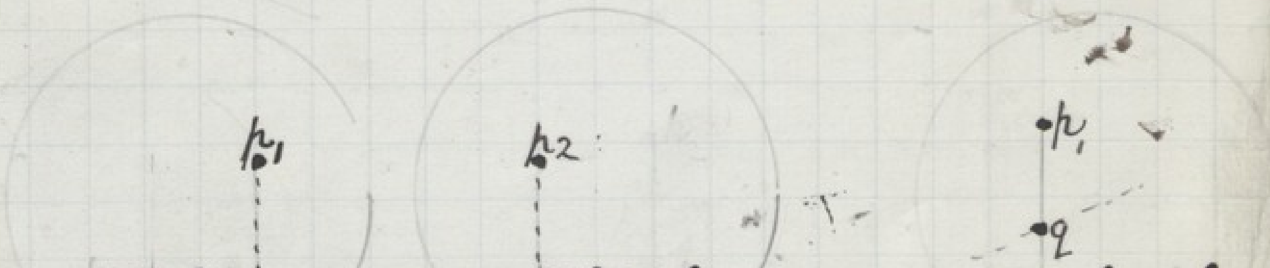


fig 5



1

2

76

f. 17b

Measurement by Photographs
first attempts.

two other fiducial points set at the further corners
of the square of which AB is the nearer side
Then their representation in the photograph a'e' and b'f'
converge to the vanishing point V and, the top of a perpendicular
rod of the same height as MN should appear in the ~~same~~
~~from X to AB shall be of the same height as MN~~
~~necessarily, and sketch~~ picture to lie in the
same horizontal line as V, otherwise the back
of the camera is not vertical. Again, e'f' should
be parallel to a'b'; otherwise the back of the
camera is not in ~~out of~~ horizontal parallelism with AB.
The distance of the camera from AB that
is the value of a, can also be determined, for
recollecting that EA = AB, ~~l, say, and that the vertical~~
~~distance between Ef and AB = AB = l, say, and that~~
the

the value of SR (fig 2) is known, calling it y as before, we have the relation

$$y : y' :: a+y : v$$

Why not use Y Y'

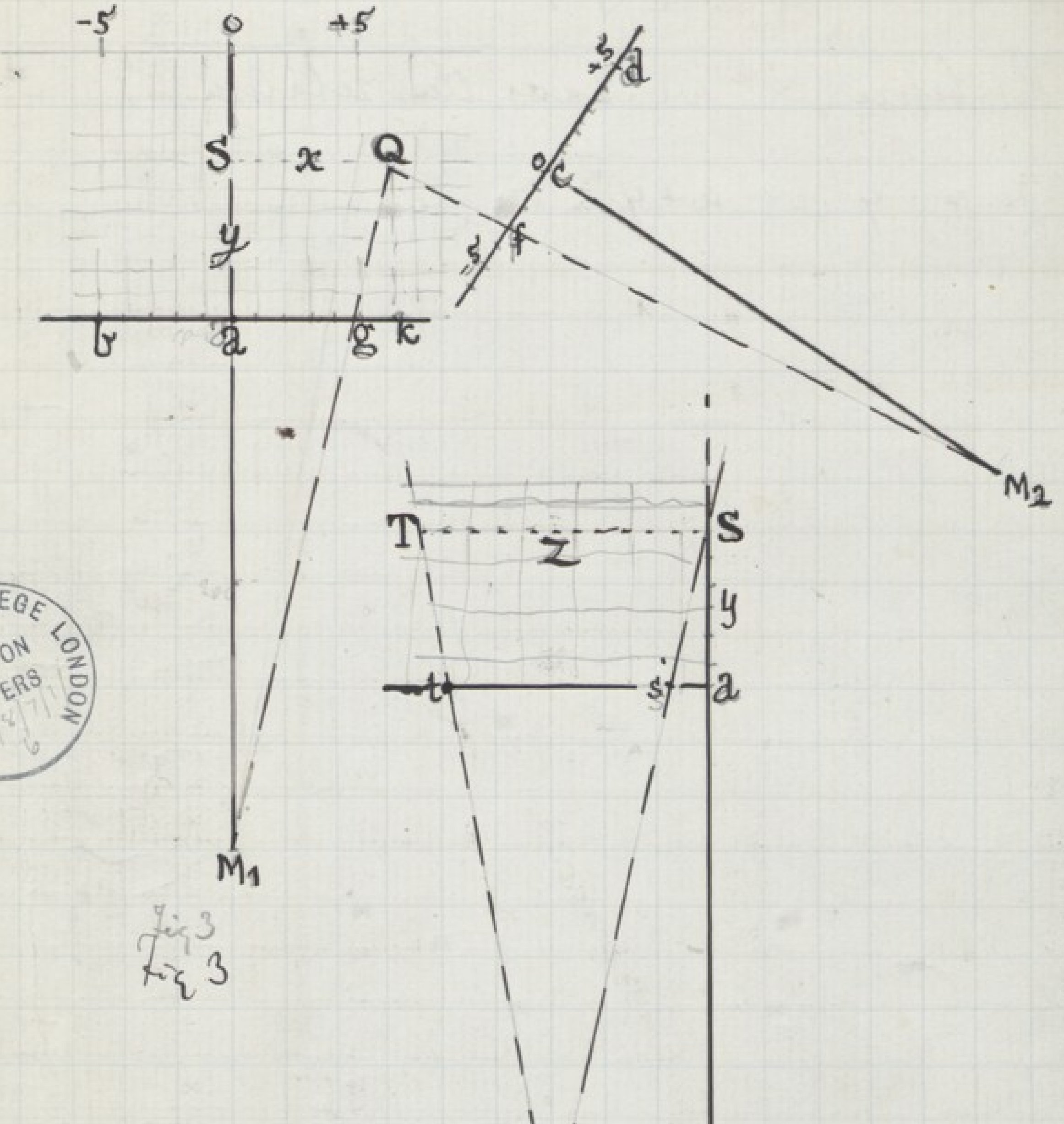


Fig 3
Fig 3

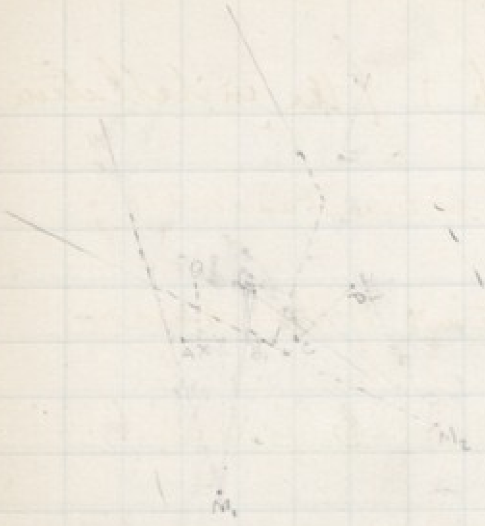
Fig 4

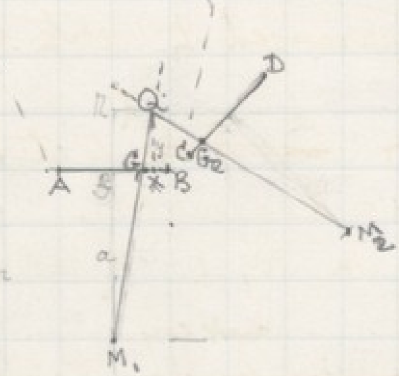
begin at p 5

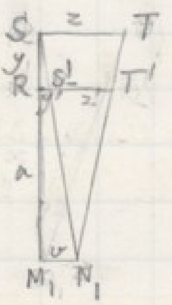
word lines pages
$9 \times 14 \times 25$

f. 1v

Drawn ½ as large again
focal lay down 40°







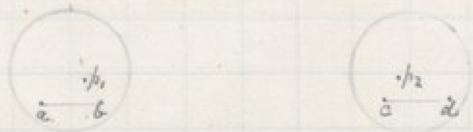


Fig. 1. ~~shows the~~ is a plan (or map) of the installation
(situated above M$_1$ and M$_2$, and which are)
of two cameras arranged to work simultaneously;

~~and~~ fig 2 shows ~~one of the~~ a vertical section of the same
(made through M$_1$ at right angles to AB.)
installation. In Fig 1 there are 6 fiducial

~~points made by~~ marks, made say, upon bricks or stones let

flush into the ground. The optical centres of

the lenses of the two cameras, N$_1$ & N$_2$, stand

vertically above M$_1$ & M$_2$, respectively, and the

height of at least one them, say of N$_1$M$_1$, is measured

and represented according to scale in Fig 2. A ~~Lines~~ ~~are~~ is drawn to connecting

A ~~and~~ with B, ~~and C with D serve as base lines, one~~ , and AB which represents a ~~being of~~ measured length is)

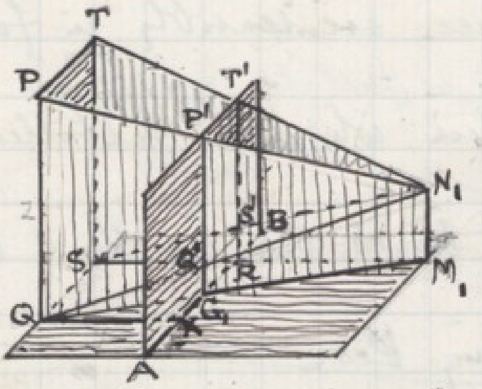
~~of them, say AB, may~~ be (suitably graduated) ~~in the~~
(to serve as a scale to the plan. A is taken as the centre whence coordinates ~~may~~ are be drawn to specify any point in the plane, the direction AB being that of the coordinate x)
plan, as the scale ~~of~~ to purpose of measurement.

(angular limits of the field of view of the cameras) omit here   in text in 16   f. Gr 6

being such as is represented in the plan, namely 40°, the field of view common to both cameras is indicated (in plan) by the strongly dotted lines. The distances of M_1 from AB = a, and of M_2 from CD = b, are such that all objects beyond those lines are sensibly in focus at the same time, when a lens is used at full aperture, a condition which is fulfilled when those distances a and b are about 70 ~~are at least 65~~ times the length of the equivalent focus of the corresponding lens.

Under these conditions the photographs of an isolated point P in space, within the common field of view of the two cameras, will be such as is shown in figs 3 & 4. In fig. 3. which has been taken by the camera M_1, there is ~~we have~~ ~~an~~ the representation of P, A and B., (there denoted by the letters) ~~distinguished as~~ p_1, a, b, and similarly in fig 4. we have p_2, c, d. It

This really represents M_2
it must be drawn differently



(5)

will be shown how these two photographs enable us to plot the two ~~two~~ horizontal coordinates of P (~~namely~~, (already stated) ~~those in X and~~ that in Y) on the plan fig. 1, ~~taking A, as~~ ~~as the centre of the coordinates and the direction AB~~ as ~~that of the axis in X~~. Then, ~~that~~ and also the vertical coordinate Z ~~of P can be determined and plotted~~ on the section fig. 2, in which the newly found value of y and ~~the~~ height of the camera, N, M, ~~[illegible]~~, are taken into account.

Fig 5 is a perspective sketch of the whole of that portion of the ~~complete~~ installation which is connected with the camera at M_1, together with the optical lines which relate ~~to the~~ ~~which we are concerned~~ to that portion. The figure includes ~~[illegible]~~ ~~contents of the~~ 5 planes ~~at right angles to one another~~, one of which is horizontal and three are ~~two are~~ vertical; they are differently shaded in the figure ~~to distinguish them~~ for distinction.

f. 7v

(AB, as the ~~of~~ intersection between
The line ~~where~~ the picture plane and the horizontal plane, is called the base line. being the only line that is common to both it ~~is~~ becomes of especial importance when ~~[illegible]~~ passing from the picture to the object)

The fourth vertical plane passes through PQ and is parallel to the picture plane.

The horizontal plane contains the points ~~A B M, Q~~ such as M, A Q B.
and others that lie ~~between A and B,~~ which ~~are~~ also ~~already~~ shown in fig 1
N, M, and the line M, RS drawn on the horizontal plane
. One of the vertical planes contains ~~PQ N, M, and others~~
at right angles to AB,) Another passes through N, M, PQ not seen as a plane either in fig 1 or 2;
(and) is shown in fig 2. The ~~other~~ third vertical plane is ~~made~~ its
intersects the horizontal one in AB
~~into line of intersection with the horizontal (plane), namely,~~

~~AXGRB being all that is seen of it in fig 1, and~~

~~its line of intersection with the vertical elevation being~~

~~all that is seen of it in fig~~ 2. This is technically

called the picture plane, because the lines drawn from all the points

in the real object to N (the eye or camera) at ~~N, form~~

intersect it, ~~and~~ their points of intersection forming

the picture, or ~~the~~ perspective representation of the object

as ~~that~~ is seen or photographed from N, [The photograph

is merely a reduction of the contents of the picture

The photographic plane ... the points A B ... [illegible]

[illegible] ... as shown in fig. 1.

$N_1 N_2$ and the line $N_1 N_2$ ... [illegible]

One of the ... planes contains ... [illegible]

... [illegible] ...

... [illegible] ... vertical plane ... [illegible]

... [illegible] ... AB

Also the suffix 1 or 2 will be used to

The ~~nomenclature~~ notation about to be used is simple. All points in the picture plane are described by capital letters with dashes such as P'; those in the photograph that come by corresponding small letters with dashes such as p'; those in the plan or section (fig. 1 & 2) by plain capitals such as P. ~~As regards~~ Points in the base line, ~~single~~ such as A might be written with equal propriety as A or as A', but the former will always be used. ~~Some~~ The same ~~letter~~ ~~points such as~~ P, ~~may~~ and representation of the same point appears ~~in both~~ differently in the two photographs; these representations are distinguished from one another by a suffix, $P'_1 p'_1$ being the perspective views of P from N_1 and $P'_2 p'_2$ those from N_2. The same notation is used for G.

those in the photograph bear the same letters but in small italics with a dash. Thus Q in the plan is Q' in the picture plane and q' in the photograph. Points in the base line such as A B might be expressed equally well either as A or as A' but the former of the two expressions will be used.

plane, without any distortion always on the understanding that the lens is a good one and that the back of the camera is parallel to the picture plane. The fact that many points in the real objects may be out of focus and not sharply defined in the photograph ~~need not~~ will be considered further ~~again~~ here, as the conditions It is sufficient now to say that the conditions of the installation ~~already~~, ~~described ensure that~~ will be such that the blurring ~~will~~ can ~~shall be slight and inconsiderable~~ never be considerable.

Referring now to fig 3 P is the point in space whose coordinates have to be determined. Q is ~~the point~~ a point on the horizontal plane where a perpendicular let fall from P meets ~~the horizontal plane~~ it. Joining NP and NQ, their intersections with the picture plane are at P'Q'. Prolong P'Q' on the picture plane till it meets which is necessary] to be added in AB Then [refer to fig 1)

base line AB
the ~~horizontal plane~~ at G) ; A line from Q drawn on the horizontal plane at right angles to AB meets AB (or AB produced when necessary) at X Then AX = x, XQ = y. which are the values to be determined from the data in figs 3 & 4

The first thing to be done is to ~~lay down the line~~ find (in the way shortly to be described) G_1, & ; then ~~laying the~~ to plot G_1 ~~down~~ on the plan fig 1, ~~the line~~ we now know from fig 2 from fig 1 that Q lies somewhere in the line $M_1 G_1$ produced. Similarly as regards G_2 to be found from fig 2. Consequently Q lies at the intersection of the two lines $M_1 G_1$, $M_2 G_2$. ~~It only remains to draw~~ Then A line is drawn on the plan fig 1) at right angles from Q to AB (produced when necessary); ~~& calling~~ ~~then~~, let ~~if~~ X be the point where the line meets AB, then ~~of intersection~~, AX = x & XQ = y which are to be measured according

Should be orthogonal projection

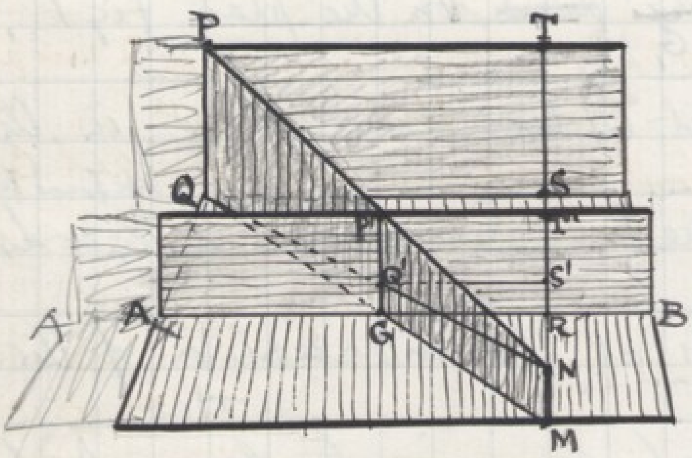


Fig 6

This is now clearly seen in fig 6, which is a bird's eye view of the same planes and lines that are shown in fig 5. The point of view is being behind & above N, in the vertical plane that passes through NM & ST. Consequently that plane appears in the fig ~~[illegible]~~ as a straight line. The perpendicularity of PG to AB and of T'R ~~and of T'R~~ is now obvious.

to the graduated scale AB.

g_1 ~~which~~ is

The position of ~~the representation of G_1~~ in

the photograph, ~~which will be called g_1~~, is

very

found by the simple process of dropping

a perpendicular from ~~P_1~~ ~~on to~~ p_1 on to

$\underline{a}\ \underline{b}$ (produced if necessary). ~~for the following~~

The reason is that PQ is by construction perpendicular

and therefore to that line in it which passing through Q runs parallel to AB

with the passes through Q parallel AB

to the horizontal plane. ~~Now~~ P'Q' ~~is~~ is parallel

Now in AB

and being produced it will meet AB at the point called G

that plane they at

to PQ, ~~is also perpendicular to it~~. Therefore

a point called G

P'Q'

~~it~~ is perpendicular to every line in the

Q'

horizontal plane, that passes through ~~G~~

the line parallel to

& therefore to the axis of X, which passes through it, consequently

but when

~~which is the point where~~ P'Q' produced meets

it is also perpendicular to AB which is the axis of x in fig 1

produced to G

AB at ~~namely through~~ G. (therefore P' G ~~...~~ is

~~that plane~~, ~~Consequently it is the $p_1\ g$ is~~

Therefore ~~P~~G is the point where a perpendicular from P meets AB

similarly

perpendicular to ~~a g b~~ A ~~...~~ B, and $p_1\ g_1$ ~~...~~ is

and similarly g_1 is the point where

from p_1 meets

a perpendicular ab A ~~By similar lin~~

~~This is best seen on fig 6 which is a perspective view of the same planes & lines shewn in fig 5 as seen from a point above & behind N~~

f. 11v

The value of AG_1 is found by measuring ag_1 and ab on the photograph; then, AB being known

$$AG_1 = AB\ \frac{ag_1}{ab}$$

and G_1 is plotted on the plan. fig 1

To ~~convert~~ the measures of the photographs ~~to~~ are converted into those of the plan, ~~for~~ $ag : ab :: AG : AB$

therefore $AG_1 = AB \frac{ag}{ab}$

ag and ab being measured on the photograph with ~~care and AB being known, AG is found with ease~~ (by the equation)

~~By~~ by a precisely similar process, G_2 is found (a plotted)

~~and~~ Then the position of Q is ~~plotted out~~ found by producing M_1G_1 and M_1G_2 in the plan until they intersect, as ~~already described~~ and the values of x and y are (upon AB) by dropping perpendiculars from Q upon the plan as already described. (G_1 ... found by dropping a perpendicular from P upon AB in the picture)

determined. It will be ~~shown~~ that ~~their~~ values of x & y are unaffected by altered N_1M_1 or N_2M_2. ~~which are the heights above the ground of the two cameras.~~

We have now to determine Z, from PQ = ~~PQ~~ (which is done by utilising) the value ~~we have~~ just obtained of y, ~~and from~~ together with

The position of T' is found by plotting the line RT' perpendicular to MRS and that

$$RT'(=G_1P') = AB\,\frac{g_1p_1}{ab}$$

(and from the measures of p, g, and ab, (in the photographs) ~~and from~~ N, M, the height of one of the cameras),

In fig 5 & 6 the lower line M, R S is drawn on the horizontal plane at right angles to AB; QS and PT are drawn parallel to AB, hence $TS = PQ = z$ and (fig 5) $SR = QX = y$. The vertical plane that passes through N, M, ~~FSR~~, & TS is ~~represented~~ shown by itself in fig 2), ~~in which~~ where (without any, ~~and not distorted~~ foreshortening perspective as in fig 5 ~~lengths M, R & SR = y~~ are true to scale, ~~and~~

~~drawing M S & N, T the length~~ of the line ~~drawn perpendicularly to M, S,~~ $RT' = G, P' - AB \frac{g_1 p_1}{ab}$

Then drawing (ST drawn from S perpendicular to M, S) ~~and~~ ~~&~~ prolonging N, T' till it meets ~~ST, T being the point of meeting it~~, the position of T is ~~defined~~ plotted and ST ~~=~~ QP = z; ~~can be~~ measured.

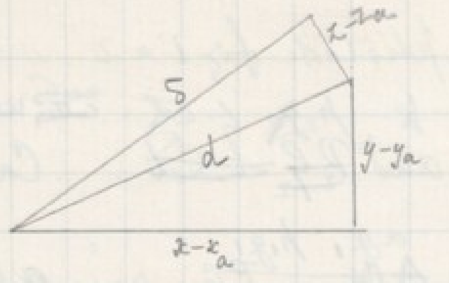
To recapitulate the entire process in a

few words :— ~~On~~ the photos fig 1 & 2 $p_1 g_1$ ~~$P_1 G_1$~~ is drawn perpendicularly from p_1 ~~to~~ ab ~~AB~~, ~~k~~ p_2 ~~g_2~~ to cd ~~and $P_2 G_2 \perp CD$~~ meeting ~~cutting~~ them respectively at g_1, g_2. Careful measures are made of ag_1, $p_1 g_1$ ~~AG_1, $P_1 G_1$~~, and ~~a~~ab ; also ~~a~~ of cg_2 and cd ($p_2 g_2$ is not wanted), these are converted into the values

$$AG_1 = AB\,\frac{ag_1}{ab}\;; \qquad CG_2 = \cancel{\frac{cg_2}{cd}}\; AB\,\frac{cg_2}{cd}\;,$$

$$P_1 G_1 = AB\,\frac{p_1 g_1}{ab}\;,$$

then ~~and~~ AG_1, CG_2 are plotted on the plan fig 2 and $P_1 G_1$ on the ~~a~~ section fig 2. ~~[illegible]~~ and the work is completed by drawing a few lines ~~[illegible]~~ and measuring ~~the~~ the results ~~are measured~~. The process which has taken long to describe, is carried out with rapidity; and moreover the coordinates of n ~~two~~ points are determined in ~~with~~ much less than n times ~~twice~~ the time required to determine those of a single ~~one~~ point.


s
z-za
d
y-ya
x-xa

Let a second point in space, P_a, be determined at the same time as P in the same way. (We may for simplicity suppose that P is the tip of one wing of a flying bird and P_a the tip of the other. Required to find the horizontal distance, d, as shown in plan, between P & P_a; also the actual distance, δ. These are easily plotted out as in Fig 6. d is the hypothenuse of the right angled triangle whose other sides are ~~respectively~~ $\pm(x - x_a)$ and $\pm(y - y_a)$, and δ is the hypothenuse of the right angled triangle whose other sides are d and $\pm(z - z_a)$. Further description is unnecessary.

Let a second point be determined at the same time in the same way (let any suppose that P is the tip of one wing of a fly, hind one P2 is the tip of the other. Required to find the length [illegible] between P & P2. Where the [illegible] distance d. There are [illegible] [illegible] is the hypothenuse of the right angled triangle whose sides are respectively $(x - x_2)$ and $(y - y_2)$ and d is the hypothenuse of the right angled triangle whose other sides are d and $(z - z_2)$. [illegible] [illegible] is unnecessary

The scale of the photographs is necessarily smaller when a ~~fixed~~ camera is used, than when it is ~~specially~~ adjusted to the ~~moveable~~ object. ~~The object may lie to the right~~ or left, or above or below the centre of the field of view, so the field must be larger than would otherwise be necessary in order to include it. Again, the object may be farther from or nearer to the camera than the point on which it is focussed and it cannot be always sharply in view unless the distance is somewhat large. Telephoto arrangements are precluded on account of the narrowness of their fields, besides they are slowly and as yet do not give strictly rectilinear images. The necessary distance of AB from the camera ~~for~~ any particular case may be easily calculated from Mr Dalmeyer's formula (~~Photo~~ Journal of Phot. Soc XX. 6 March 30 1896 ?) ... above the lens — from the optical centre of the lens — ...

Let ... for

the object is in motion. Leaving aside the question of how best to measure the glass negatives ~~photographs~~ with a microscope & micrometer, ~~there~~ or by lanthorn enlargements thrown down on a paper, I find that ~~the~~ paper prints can best be dealt with by pricking through the points that have to be measured with a fine needle, and ~~doing~~ plotting the work on the back of the print in fine pencil lines using a lens.

but it would be easier to determine experimentally, ...

The photographs are necessarily on a very [s]mall scale, telephoto arrangements being [ra]rely applicable on account of the small angle [o]f their field of view. Also they do not profess [t]o be as strictly rectilinear as may be desirable while [th]eir relative slowness ~~is~~ of action another objection when [th]e object is in motion. Leaving aside the question of how best to measure the glass negatives ~~photographs~~ with a microscope & micrometer, ~~there~~ or by lanthorn enlargements thrown down on a paper, I find that ~~the~~ paper prints can best be dealt with by pricking through the points that have to be measured with a fine needle, and ~~doing~~ plotting the work on the back of the print in fine pencil lines using a lens.

The advantages of this method are great. If the point is not sharp in the photograph it is still possible to estimate the centre of ~~its~~ position notwithstanding the blur, and to ~~clearly~~ fix that position with deliberation by the prick mark ~~may~~ which is so small as to be invisible on the ~~side~~ face of the print ~~& often~~ even sometimes requiring a lens to find it in its plain back. When the place of the prick mark is defined ~~found, its position is made~~ clear by surrounding it with a small ~~pencil~~ circle in pencil. The measurement between such points of these on the plain back of the print is very easy, and the all work is preserved ready for reexamination should any suspicion arise of inaccuracy. I have employed prick marks for other purposes to a large extent & am more than satisfied ~~with their efficiency~~.

Latterly I have used a microscope with an attached working pricker underneath it, & find it most easy to make distinctly legible ~~prick~~ holes whose centres are less than 100th of an inch (¼ millimetre) apart. I have ~~almost~~ made them without difficulty at even 150th of an inch, but a 200th is just beyond the ~~limit~~ of the powers of the method. The needle ~~must~~ should be very fine & there should be a check to prevent its penetrating too far and becoming blunted. ~~I am not quite satisfied with~~ My microscope & pricker could be improved by making it ~~as it could obviously be made~~ both lighter & more rigid, so I do not describe it ~~further~~. in detail

Another class of cases has now to be considered in which only one photograph is needed to determine x, y and z. It consists of those in which a representation of Q is ~~shown~~ appears in the print or where its position can be inferred. The position of Q ~~It~~ is shown, as when P is the top of a ~~vertical column~~ the corner of a house whose base Q is visible; It can be ~~is~~ inferred, ~~as~~ when P is some point, say, along the back or belly of a horse ~~at~~ rest, whose feet are seen; ~~by bisected~~ the (in the photograph) interval (narrows) between symmetrical points in the fore feet is bisected, also that between others in the hind feet, then the line that connects the points of bisection ~~represents~~ corresponds to the intersection with the ground of a vertical plane passing through the spine or middle of the belly of the horse. A perpendicular from p' ~~P~~ cuts this line in q' ~~Q~~, and (and being prolonged, it cuts) $a'b'$ ~~AB~~ as ~~before~~ already explained, in g' ~~G~~.

~~(As before, Referring to fig 2) and recollecting~~

~~that RS' = GQ' = AB $\frac{gq'}{ab}$, the line N, S' produced~~

~~cuts M, R produced~~

Referring to fig 2, ~~and~~ recollecting that

$RS' = GQ' = AB \frac{gq'}{ab}$ and plotting RS', then, the prolongations of

M, R and N, S' intersect at S; S is determined and hence, RS = y ~~is~~ can be

~~determined~~ measured. Again, plotting RT' = G'P' = AB $\frac{g'p'}{ab}$

and prolonging N, T' till it meets the perpendicular

~~to~~ S at T, the length ST = z is also determined

The intersection of a line drawn in the plan fig 1

through S ~~and Q and therefore~~ parallel to AB

and therefore, running somewhere through Q, with M, G, produced ~~is intersected~~

determines ~~at~~ Q, ~~by M, G, produced~~. A perpendicular from

Q meets AB in X, where ~~AX~~ AX = x. Thus all 3 coordinates

16
12
1914

$$y' = \frac{vy}{a+y}$$

$$\frac{y'}{y} = \frac{v}{a+y}$$

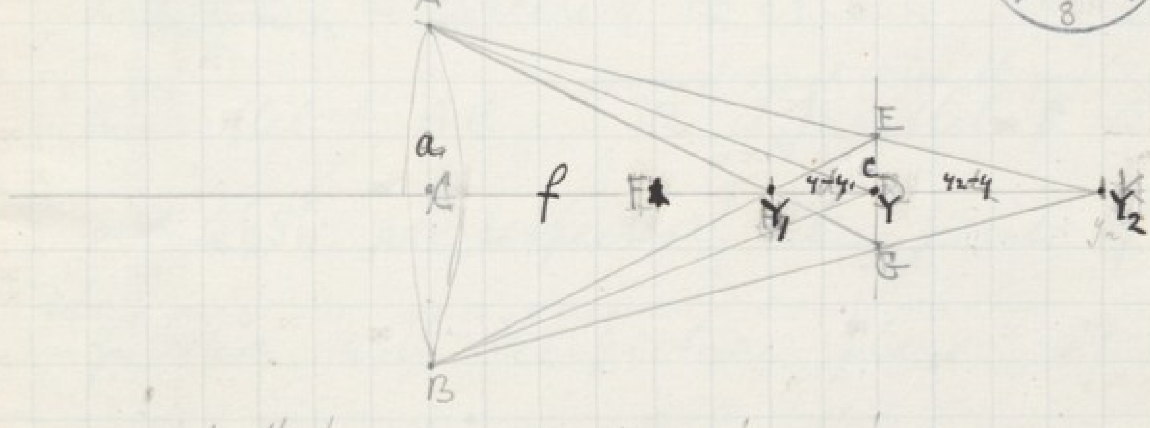
are found.

It is necessary that M_1N_1 should be somewhat high else ~~the~~ y becomes so much foreshortening in the photograph that its value may be seriously affected by a small error in the measured length of qq'. Good results were got with my installation in which f, the equivalent focus of my portrait lens, $= 2.76$ inches, $a = 200$ inches, $M_1N_1 = 60$ inches therefore $\frac{a}{f} = 72.5$ all objects beyond a were then in focus, ~~and the foreshortening (of qq') in the neighbourhood of AB was approximately being $\frac{RS'}{y'} : y$ is determined from the relation~~ Here the foreshortened value of $y = RS'$ $= y'$ & y' is determined by the relation of

$$y' : v :: y : a+y \quad \text{whence} \quad \frac{y'}{y} = \frac{v}{a+y}.$$

If the distance of P

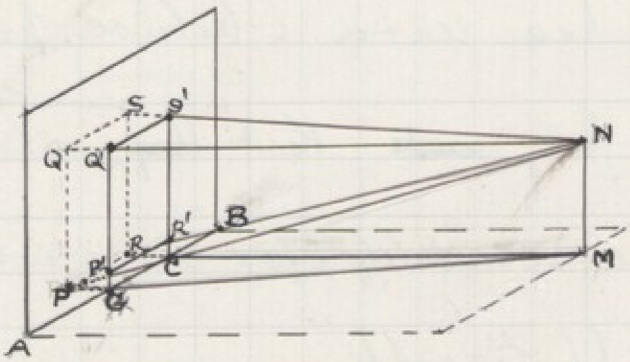
to be brought into general use, while measures, I have reason to believe from ~~some~~ the experiments thus far, ~~made~~ that ~~they~~ those measurements the required could be made ~~performed~~ more accurately & as well as far more easily and inexpensively by photography.



CF = length of equivalent focus. $\frac{1}{AB} = \frac{1}{AF} + \frac{1}{AX}$ writing

~~Let~~ CED G be the position of the focussing screen of the camera, when ~~at~~ an object at a distance CD on the opposite side of the lens comes sharply to a point upon it. Let EG be the diameter of the greatest permissible circle of confusion. Join AG BE intersecting at H, join AE BG & produce them until they intersect in K. Let Ch be the distance of the conjugate focus to H and Ck that to K. Then Ch will be the distance of the farthest object, and Ck that of the nearest that will appear tolerably sharp when the focussing screen is at D. These are the values we have to find

Simplifying the ordinary formula of $\frac{1}{F} = \frac{1}{F'} + \frac{1}{F''}$ by writing F+x for f & F+y for y we get $xy = f^2$



S
S'
Q
Q'
N
R'
B
R
P'
C
M
P
G
A

picture-plane with the ground. The ~~square~~ square bounded by ABLK

fig I may be called regarded as a ~~the~~ the "picture frame"; it

includes so much of the transparent picture-plane as is

wanted ~~now~~. ~~P & Q have~~ MCR is a perpendicular

drawn through AB, along ~~on~~ from M the surface of the level ground, from

which is taken as the point from which the

~~M through AB~~ & intersecting ~~it~~ AB at C. QS

is drawn parallel to AB. SR is drawn of equal in length and parallel to QP.

P' R' Q' & S' are respectively the points of

intersection with the picture-plane of lines

drawn from N the point of sight, to PRQ & S.

R'S', P'Q', respectively prolonged downwards, meets AB in C & G.

a line ~~from Q drawn~~ on the ground drawn from Q parallel

to SCM meets AB in X. It will now

be seen that the 3 coordinates (in space) of P, which are $CX = x$, $XQ = CS = y$, $PQ = RS = z$, appear

$$\frac{z'(a+y)}{a}$$

Fig 2) shows that $y = QX = SC$, $y' = QG = S'C$, $z = PQ = RS$

$z' = P'Q' = R'S'$. Also, V being the vanishing point, $VC = NM = v$ ~~let MC~~ $= a$ and all lines which in reality are parallel to NV', converge perspectively towards V; thus the line XQ fig 2 assumes the perspective appearance of XQ'V' see fig 1.

f. 3r 11

$CG = z'$, $GQ' = CS = y'$, $Q'P' = S'R' = z$ ~~$CG = x'$, GQ' etc~~ $= y'$ ~~$S'R' = z'$~~

perspectively in Fig 2 as ~~as $AX = x$~~, $SC =$ ~~$XQ = y$~~

~~and $QP = z$~~ ; ~~the true values of these latter have now to be found in terms of~~ the line AB

~~which~~ being common both to the real objects & to the ~~perspective of them~~ ~~in the~~ picture plane ~~with which we have to deal~~ Fig 1 serves as the scale ~~of measure~~ by which measurements are made on both. ~~for both are me~~

Fig (2) shews that, PQ = RS, ~~and~~ P'Q' = R'S', ~~also and~~ (QX = SC , Q'G = S'C) These latter values are ~~those~~ alone used in figs (3) & (4)

~~where SR(=z) : S'R'(=z') :: MS(= a+y) : MC(=a)~~

~~whence z =~~

From either fig (2) or fig (3)

f.3v

$$yv = yy' + ay' \qquad y = \frac{ay'}{v-y'}$$

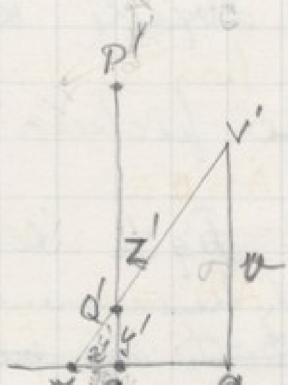
$$az = yz' + az' = \frac{ay'z' + avz' - az'y'}{v-y'} = \frac{avz'}{v-y'}$$

$$z = \frac{vz'}{v-y'}$$

Centre of Coordinates th[illegible] at C $az = CX$

$CX = x : CV' = v = GX = y : GQ' = y'$

$GX : XQ = a = GC : a$



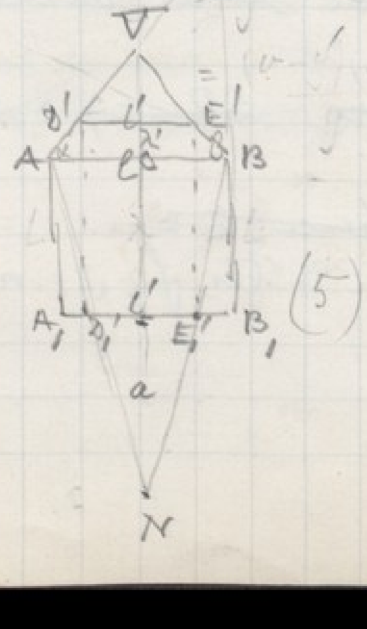
$XG : GQ' = x : v$

$XG : y = GC : a \qquad x' : x = v : y'$

$$x = \frac{x'y'}{v}$$

$$vl' = vl - l\lambda'$$

$$v = \frac{l\lambda'}{l-l'}$$



$AC^2 + v^2 = AV^2$

$(l^2 - AC)^2 + v^2 = VB^2$

$y : y' = SC : S'C = y + a : v$, whence $y = \frac{ay'}{v - y'}$ (1)

$z : z' = SR : S'R' = y + a : a$, whence $z = \frac{vz'}{v - y'}$ (2)

$x : x' = v : y'$ $x = \frac{vx'}{y'}$ (3)

The values of a and $v = c$ in the above equations may be derived from measures made on the picture, of the four fiducial marks $A'B'D'E'$

Let $A'B' = L$ $D'E' = L'$, $S_1'C' = \lambda'$ (the letter S_1' is used to distinguish it from S' in fig 2, when the fiducial points form a rectangle whose sides are shorter than its base, and not a square as for convenience sake we are now supposing)

$L : L' = a + L : a$ whence $a = \frac{L^2}{L - L'}$ (4)

$L : \lambda' = v : v - \lambda'$ $v = \frac{L\lambda'}{L - L'}$ (5)

C is found graphically by drawing a perpendicular on AB otherwise the L^s VAB VBA w^d have to be measured. AC = v cotan α
It is convenient to establish that $AC = \frac{1}{2} AB$

f. 5r

the decimal scale to be used for such purposes as there otherwise I should certainly propose that AB should be made equal to 2½ metres, and the metric scale employed throughout.

[Copied]

It will be well to give the formulae

let $AB = l$, $D'E' = l'$, and for consistency of notation call the side of the square λ

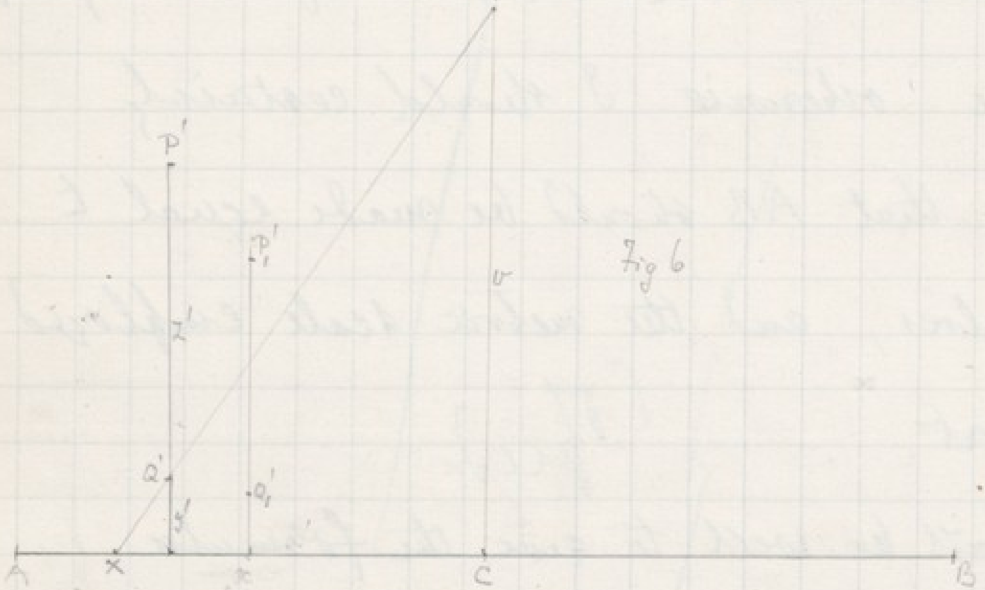


Fig 6

Example AB = 120 units $a = 240$ $v' = 70$ CM

for P $x' = 30$ $x = \frac{70 \times 30}{60} = 35$

$y' = 10$

$z' = 40$ $y = \frac{240 \times 10}{60} = 40$

$z = \cancel{\frac{40 \times 70 \times 40}{70 \times 240}} = \frac{28}{6} = 4.67$

or $\frac{70}{60} \times 40 = \frac{28}{6}$ as above

or again for P_1

$x_1' = 20$ $x_1 = \frac{70 \times 20}{62} = \frac{1400}{62} = 22.6$

$y_1' = 8$ $y_1 = \frac{240 \times 8}{62} = \frac{1920}{62} = 31.0$

$z_1' = 30$ $z_1 = \frac{70 \times 30}{62} = \frac{2100}{62} = 33.9$

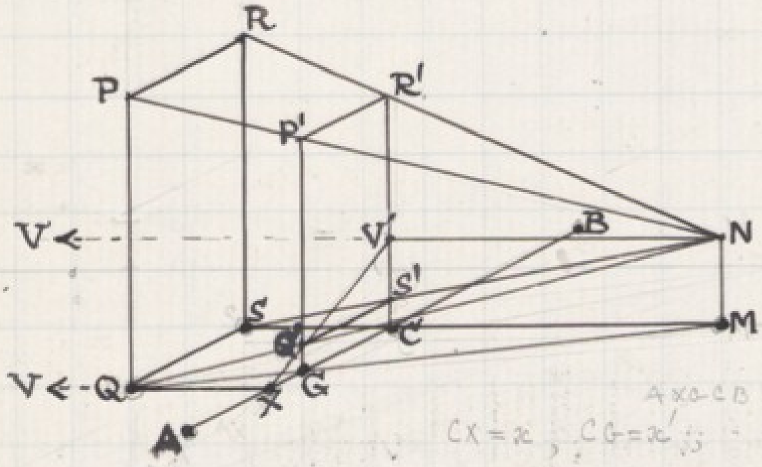
hence horizontal distance from PEP_1 = $QQ_1 = \sqrt{\{(x-x_1)^2 + (y-y_1)^2\}} = d$ say

actual distance $PP_1 = \sqrt{\{d^2 + (z-z_1)^2}$

both of these may also be obtained graphically by obvious methods

$d = \sqrt{\{12.8^2 + 9^2\}} = \sqrt{(164 + 81)} = \sqrt{245} = 15.75$

$D = \sqrt{\{245 + (12.4)^2\}} = \sqrt{\{245 + 154\}} = \sqrt{\{399\}} =$



N is the position of the eye (or Camera)

The lines QS, AXGCB, and M

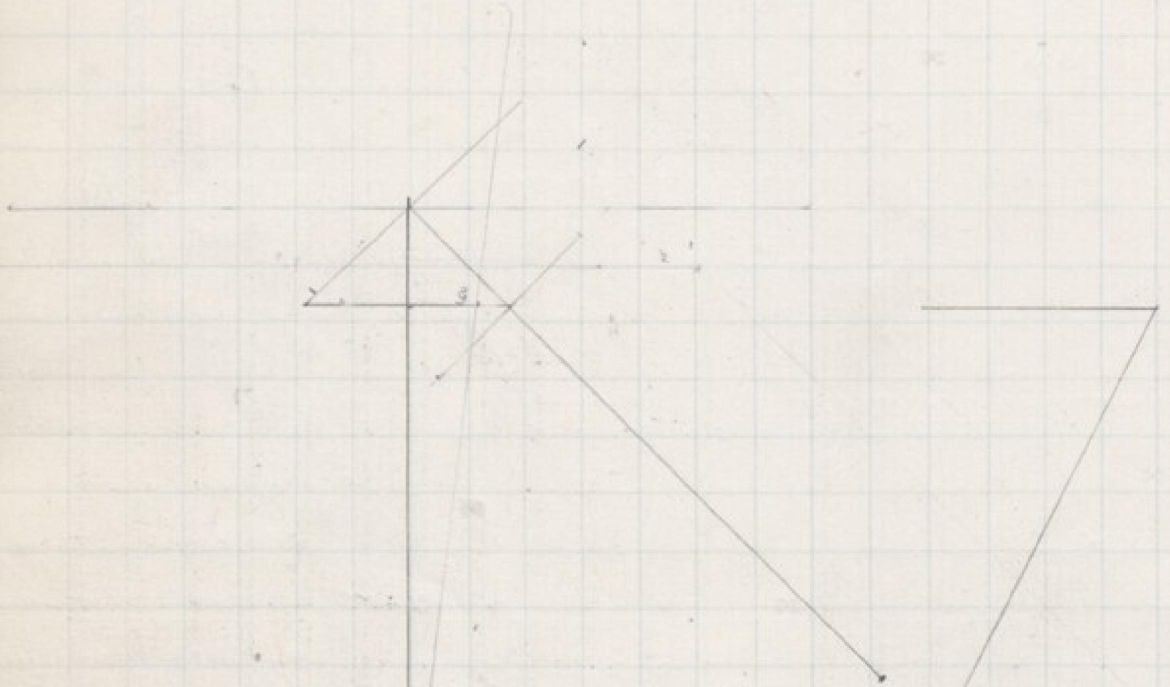
and the point M are all on the ground.

AXGCB is the intersection of the vertical [illegible] plane with the ground

$CX = x$, $CG = x'$; $XQ = CX = y$; $GQ' = CS' = y$

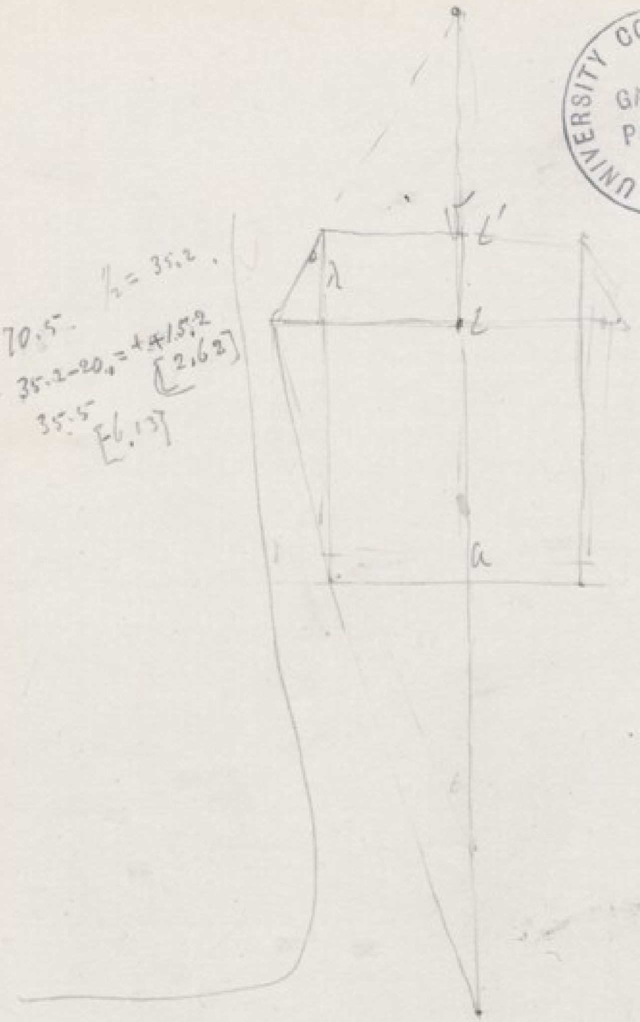
$PQ = RS = z$, $PQ' = R'S' = z'$. $MN = CV' = v$; $MC = a$

f. 11v



V

f. 12



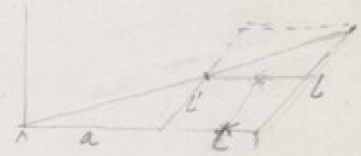
diag 70.5. $\frac{1}{2} = 35.2$.
C l ⊥ 35.2−20.0 = ~~+~~ 15.2 [2.62]
[illegible] 35.5 [6.13]

$v : \frac{l}{2} :: v-\lambda : \frac{l'}{2}$

$v : l :: v-\lambda : l'$

$vl' = vl - \lambda l$

$v = \frac{\lambda l}{l - l'}$



$l : l' :: a+l : a$

$al = al' + ll'$

$a = \frac{ll'}{l-l'}$ $l - l' = 14$ $l' = 44$, $l = 58$, $\lambda = 14$

$a = \frac{44 \times 58}{14} = \frac{2552}{14} = 182$

$v = \frac{3.4 \times 10}{2.4} = \frac{340}{24} = 14.2$

58 : 10 :: measured length : x

$x = \frac{10 \times \text{measured length}}{58}$

L * add 5

$l = 10$
$l' = \frac{440}{58} = 7.6$
$\lambda = \frac{140}{58} = 3.4$

$l - l' = 2.4$

$a \quad \frac{182 \times 10}{58} = 31$
$a + l \quad = 36$

Measures of Photog

№ 3

Measures by Photog

[No 3]

f. 1

3 Photos at Kew Obs with my miniature lens

Measures by Photog

No 3

$$z = \frac{md \cdot \xi}{m\delta - dx}$$

$m = 60''.2$ $d = 50''.0$ $\delta = 19.5^{m}$

$md = 3010$; $m\delta = 1174$

	GP	GQ = x The bottom is 1/2 ...	GP−GQ = ξ	$md\xi$	dx	$m\delta - dx$	z calc	z obs
A	23.3	3.3	20.0	60200	165	1009	59.6	60.6
B	23.2	2.9	20.3.	611..	145	1029	59.4	60.6
C	7.6	3.3	4.3	129..	215	959	13.5	60.6
D	17.8	3.1	14.7	442..	155	1019	43.4	44.5
E	17.6	2.4	15.2	458..	120	1054	43.7	44.5
F	12.7	2.7	10.0	301..	135	1039	29.0	29.6
G	7.6	3.3	4.3	129	215	959	13.5	13.7
H	-							13.6
J	6.7	2.0	4.7	141	100	1074	13.1	13.5
L	14.0	1.8	12.2	367	90	1084	34	27.7

No (1)

$m = 57''.75$ $d = 45''.0$ $\delta = 26.6$ mm

$md = 2600$ $m\delta = 1536$ $\frac{A}{C}$

	GP	GQ = x	GP−GQ = ξ	$md\xi$ (A)	dx (B)	$m\delta - dx$ (C)	z calc	z obs	diff
A	35.4	9.5	25.9	67340	428	1108	60.6	60.6	0.0
B	35.6	6.6	29.0	75400	297	1239	60.8	60.8	0.2
C	35.8	3.4	32.4	84240	153	1383	61.0	60.6	0.4
D	28.2	8.3	19.9	51740	374	1162	44.6	44.5	0.1
E	27.6	4.7	22.9	59540	212	1324	45.1	44.5	0.4
F	20.9	6.1	14.8	38480	275	1261	30.6	29.6	1.0
G	14.3	8.0	6.3	16120	360	1176	13.7	13.7	0.0
H	13.0	6.0	7.0	18200	270	1266	14.4	13.6	0.8
J	11.6	4.2	7.4	19240	189	1347	14.2	13.5	0.7
K	29.3	8.0	21.3	55380	360	1176	47.0	47.5	0.5
L	13.8	4.0	9.8	25480	180	1356	18.8	27.75	1.0
M	30.4	4.0	25.4	66040	180	1356	48.5	52.4	3.9

F.3

No. 2)

$m = 57.75$ ind
$d = 50.0$ "
$\delta = 26.0$ mms.

$$Z = \frac{md\,\zeta}{m\delta - d\chi}$$

$md = 2887$
$m\delta = 1502$

26×57.75

The base of the lower very indistinct. fiducial points in photos not clear.

	GP	χ GQ	ζ GP-GQ	$md\zeta$ 289 × ζ (A)	$d\chi$ 50×χ	$m\delta - d\chi$ 1502−$d\chi$ (B)	$\frac{A}{B}$ Z calc	Z obs	diffce
A	31.5	4.0	27.5	79475	200	1302	61.1	60.6	+ 0.5
B	31.7	2.0	29.7	85833	100	1402	61.0	60.6	+ 0.4
C		indistinct							
D	24.0	2.7	22.3	64447	135	1367	47.0	43.4	+ 3.6 ×
E	23.5	0.3	23.2	67048	15	1487	45.0	43.7	+ 1.3
F	16.7	1.6	15.1	43639	80	1422	30.7	29.0	+ 1.7
G	10.5	3.2	7.3	21097	160	1342	15.8	13.5	+ 2.3
H	9.0	1.5	7.5	21675	75	1427	15.3	13.6	+ 1.7
J									
K		indistinct							
L									
M									
		Tried a different base							
A	31.3	4.3	27.0	7803	215	1287	60.5	60.6	.1
B	31.4	1.8	29.6	8554.4	90	1412	60.7	60.7	.0
D	23.8	3.1	20.7	5982.3	155	1347	44.4	43.4	1.0
F	16.6	2.2 very?	14.4	4162	110	1392	29.7	29.0	0.7

All are +

fresh measure

f. 1 1

Architectural draughtsmen are familiar with the ~~arts~~ of translating objects into their perspective representations ~~of them~~, but the converse process of translating perspectives into their objective equivalents has never, I believe, been yet brought into practice. So long as pictures had to be drawn by hand, and therefore inexactly, there was no inducement to consider the possibilities of this converse process, for which exactitude in the ~~perspective~~ picture is ~~an~~ essential to success, but now that photography has become ~~a~~ common, ~~and~~ the old difficulty has disappeared, and the possibilities of the neglected process well deserves consideration.

Its applications would be numerous and especially valuable in determining and measuring restless animals in their momentary attitudes, or even when in rapid motion, who could not otherwise be measured ~~at all~~ ~~or only~~ without difficulty; (or even when they were in rapid movement when they could not otherwise be measured at all.) The object I have especially in view is to establish a system of measuring a large number of domestic animals, singly or in groups, of various pedigree stocks, whether of horses, cattle, sheep, dogs, poultry &c., in order to provide material (of a kind that is greatly needed.) to advance our present ~~imperfect~~ knowledge of heredity. It is not qualitative facts and exceptional instances that are now wanted (by students of heredity), but a ~~thorough system~~ large collection of quantitative ~~data~~ facts, in the (trustworthy) form of ~~exact~~ measurements. They ~~data~~ are needed to determine with far greater precision than they are at present known, the statistical laws and coefficients of heredity. Among these are the conditions and rate of "regression" of the offspring of exceptional parents; ~~towards mediocrity;~~ the gradual or sudden alterations of the position of the point towards which regression tends, as the breed becomes more pure; the relative influence of the male & female parent in respect to various measurable peculiarities; the ~~frequency and~~ intensity of prepotencies; the frequency and magnitudes ~~intensity~~ of sudden sports, and the degrees of their subsequent stability through successive generations. Animals of pedigree stock are exceptionally appropriate subjects for such inquiries. They are all carefully tended and watched, and ~~yet~~ they are very numerous, upwards of 2000 foals of race horses alone, being annually produced and entered

f.4 4

in the Stud-book, ~~by~~ through which means the names & racing performance of every member of their ancestry for very many generations, can be ascertained. Thus an enormous amount of material exists, capable of being ~~might be~~ turned to account in a way ~~most~~ particularly acceptable to the breeders of ~~owners of the~~ stock, but which now is unused; It seems probable that ~~and it~~ would be largely turned to account ~~by establishing of a method~~ installing of due arrangements for photographic portraiture of an inexpensive kind were installed at the frequent prize ~~of inexpensive photography, at~~ shows of pedigree all kinds of animals ~~stock~~, such as should produce ~~portraits of the~~ sufficiently good portraits of the animals ~~animals good enough~~ to induce the exhibitors of ~~owners of the stock to~~ to apply for and buy them, whole ~~and~~ at the same time those pictures should be taken under conditions that would make them available for scientific purposes. ~~the measurement~~. It is the main object of this paper to explain what those conditions

(that will be arrived at may be briefly)
are, & the general results ~~may be~~ mentioned now.
They are, that a single photograph including certain
small fiducial marks in the ground (~~each~~ not
larger than pebbles, ~~such as might be made~~
and level with its surface)
~~by chiselling a cross into bricks let into the soil~~
~~level with its surface~~) suffices to ~~give~~ allow of at least
(being made of a horse, namely the height of his withers, of his croup, the depth of his chest and the length of his body)
four important measures. In other cases, a
second & subsidiary photograph ~~has to be taken~~
(has to be made) (with the first one.)
of the animal simultaneously. The stand,
if only one camera is used, or stands if there are two, ~~always~~ ~~stands~~ in the same ~~position~~ way,
~~on which the camera is to be placed~~, are supposed to be ~~is to~~ fixtures,
and the cameras to fit into bearings upon them. Their
~~its~~ heights above the ground, their ~~its~~ distances from
the fiducial marks & their ~~its~~ positions in relation
and the focus of the camera is to be kept unchanged
to them being once for all determined. Under
these conditions the animal is led as nearly as

nearly as may be to the destined positions and the two photographs are ~~then~~ made from ~~taken by~~ brief exposures. It will be seen that these conditions require the use of a ~~portrait~~ lens of short focus, and ~~a portrait of a~~ wide aperture yielding a ~~miniature portrait~~ negative of only miniature size ~~afterwards affording prints, as enlargements in paper, in the camera, of about~~ whence prints are to be made in the form of paper enlargements in the camera.

Beautiful photographs, each a costly study in itself, are now ~~made~~ taken of the prize animals at various shows, but they are useless for measurement, whereas the unpretentious portraits that I have briefly alluded to yield all that can reasonably be wanted for that purpose

I ~~may~~ should add that, the direct measurement of creatures so sensitive, timid, and ~~so~~ sudden in their actions as thoroughbred horses, who (at the same time are ~~also~~) ~~are~~ often vicious, ~~as well~~, ~~is dangerous as well as difficult~~ is ~~not only~~ difficult ~~but~~ and dangerous; similarly ~~and the same is true of other pedigree stock such~~ much as regards bulls and of the breeds of some dogs. Photography is a ~~both~~ simpler, more exact & far safer method of measurement in these cases than the direct (application of rod, tape &c all ~~together~~).

Some notion of the kind of accuracy that is required, ought to be kept before the mind while reading ~~what follows~~ this paper. The height of the withers of a horse and that of a man may both be roughly taken at ~~5½ feet~~ 66 inches (that is 16½ "hands" (with the ~~terms~~ units of measurement usually employed) for the former, and 5 ~~½~~ feet 6 inches for ~~in~~ the latter) ~~case~~ Hence the

f. 7v

~~The dis~~ In an ordinary photograph the reduction from the actual size of the animal is about $\frac{1}{25}$, in which case 1 inch in reality becomes $\frac{1}{25}$ inch ~~inch~~ or 1 millimetre in the photograph when there is no foreshortening. Now it is easy to deal with half that length either by measurement or in drawing lines.

f. 8 8

apparent height of either ~~of them~~ horse or man when ~~the~~ ~~(probable~~ ~~their~~ his distance from the camera is changed to the amount of only one sixty sixth part of its original amount, ~~has~~ is increased or diminished as the case may be, by about one inch. ~~Therefore~~ In other words, one inch of error in the measurement will ~~this~~ a liability ~~amount of error will~~ be created by ~~correspond to~~ an ~~uncertainty~~ error in position of only 1 inch at a distance of 5½ feet, of 2 inches at 11 feet, of 4 inches at 22 feet, & so on. If even an error of one inch be the acceptant only against ~~largest that is~~ tolerable, the ~~requisite~~ great precision of the picture that is requisite for even that small amount of precision may be inferred; still, it is by no means beyond the power of photography to obtain greater exactness than this ~~and as much~~. ~~as will be shown~~ ~~On the other hand, the~~ The direct ~~direct~~ measurement of horses are only by no means satisfactory results, as ~~I found~~ appears from ~~the~~ ~~results of~~ trials kindly made for me by the Principal

f.9 9

of the Royal Veterinary College, Dr Fadyean. He caused each of 5 different selected dimensions, in each of 5 different horses, to be severally measured 5 times over, by each of 5 different students, under conditions that ensured as far as possible, independence in the measuring. I give the results at length in the Appendix. The errors of each measurer reckoned inter se, ~~[illegible]~~ ~~and~~ and the ~~err~~ average error of one measurer as compared to that of another were so large that ~~as much as~~ no loss in the value of the conclusions would occur, by taking an inch as the smallest unit of measure for the larger dimensions (such as height & length of body &c) and disregarding fractions) ~~Fractions~~ of an inch. ~~are not worth regarding. On the other hand the difference of height, &c in a~~

~~photograph of ordinary size is about 1 millimetre which the eye, unassisted by a lens can easily subdivide into 2 parts.~~ On the other hand ~~The last point to be considered is~~ the variability of the animal is considerable.

I measured numerous photographs of the ordinary kind of horses, which gave one datum ~~with~~ trustworthily, namely the relation between the height at the withers and the depth of the chest. These were obtained by drawing a line ~~between~~ that halved the distance between the two fore and the two hind feet respectively and dropping a verticals upon it from the withers, and from the bottom of the chest. Also I made other measures on such photographs of race horses, as appeared to be standing nearly in the same perspective attitudes.

The general result ~~arrived at~~ was that race horses, notwithstanding their interbreeding and consequent similarity, could apparently be differentiated, and indexed by their measures to the nearest inch, ~~about~~ almost as surely as prisoners are dealt with by the anthropometric method of Bertillon. The ~~ratio between~~ average error of measurement (should large in itself appears) to be so much smaller than the ~~and~~ average variation of the race horse, that the ~~use of~~ attempt, to employ ~~ment~~ ~~of these~~ measurements, ~~in order~~ to ~~determine~~ afford the ~~above mentioned~~ desiderata in the theory of heredity, as mentioned above, is quite justified & similarly as I infer for ~~all~~ others of ~~other kinds of~~ pedigree stock, generally, with the exception of those ~~that are~~ whose outlines cannot be seen owing to a (very shaggy) covering of ~~with~~ wool or hair. ~~being excepted~~

The subject will be treated at first as one of ordinary perspective, the limitations introduced by photography in respect to the necessity of all the picture being in focus, and to the width of the field of view being considered and disposed of afterwards.

It has already been mentioned that certain measures can be obtained from a single picture; they are defined as follows. Let P be a given point in an object, and let a perpendicular be let fall from P to the ground, meeting the ground at Q, then PQ is the height of the object, which we will call z, ~~also~~ the position of Q on the ground in reference to ~~any~~ two fiducial points can be defined ~~in determin~~ in the usual way, by its two coordinates x and y. Now if both P and Q ~~are given~~ appear in the picture as P' and Q', ~~and~~ then calling from the two ~~coord~~ perspective coordinates of Q' ~~by the way~~ ~~being~~ namely called x' and y', we

are able to determine)
~~shall see that~~ x, y, z, ~~can be determined by~~
~~measuring x' y' and z'~~ certain ~~constants~~ values
in the installation being known. ~~But if~~ Now
in many cases Q' either appears in the picture or due its position in it can be inferred
from the ~~positions~~ those of ~~the~~ neighbouring objects. ~~in many cases~~. If PQ be a vertical post, then Q' is situated
at the place in the picture where the post is seen to emerge~~s~~ from the ground
If P' be situated any-where along the back of a
horse or along the belly, Q' will be situated at
the ~~intersection~~ point where of a perpendicular from P' meets ~~with~~
a line drawn, as already described, between
the hoofs, that line ~~is~~ being the intersection of a vertical
plane passing through the spine, ~~and~~ with the ground.
This class of cases will be) ~~considered first~~.
~~and will be~~ fully disposed of, photography and all, before
entering on the second class of cases which ~~will~~ can then be ~~easily~~ shortly dealt with.

Four diagrams are ~~used~~ inserted for explanation

Fig. 1. represents the picture that has to be dealt with. The meanings of P', Q' have already being explained. A ~~A~~, and B

~~are the 2 fiducial marks e.... say AB = 10 feet~~
~~C is a point in the middle between them~~
~~and CQ = 5 feet from either~~

are ~~the~~ 2 fiducial marks; & it is proposed when ~~in~~ dealing with horses ~~practice~~ to take AB = 10 feet &. C is a very important point; it is that ~~point where a line~~ at which an horizontal line drawn from the foot of the camera, cuts AB at right angles; (it is the centre whence the coordinates will start.) There is no necessity to mark C if AC be known but it is convenient to do so on account of its importance, also so to ~~arrange~~ adjust the position of the camera that C shall lie half way between A and B, or & 5 feet from each. CV' is a perpendicular ~~drawn~~ upon from AB at C, and of ~~such~~ a length equal to the height of the camera. This it is proposed to take = 5 feet = CA or CB. Therefore AV′ is drawn very easily. V′ is the vanishing point of all ~~par~~ lines that are in reality horizontal, and at the same time at right angles to AB. Thus let D′, E′, in the picture, represent ~~be~~ two additional fiducial marks D, E, so disposed ~~in reference to A, B~~, that A, B, D, E shall lie ~~indicate~~d the four corners of a square 10 feet in the side, then AD′ and BE′ when produced, will converge at V′. ~~to~~

~~or~~ The existence of these 5 fiducial marks instead of using the minimum of 2, is advantageous in two ways. They enable the ~~process of~~ measurements of the photograph to be effected more speedily than otherwise, and they control or even ~~take~~ may be used to determine the ~~place of the~~ principal constants in the installation. Thus (1) V′ is found by the convergence of AD′ and BE′, ~~the given~~ (2) the fact that a line from the camera at right angles to AB really cuts AB in ~~at the~~ middle point C, (as it should do,) ~~is shown~~ by a perpendicular from C cutting D′E′ also in its middle ~~also~~ (at F, which might well be a 6th fiducial mark). (3) the height of the camera is given by CV′, and (4) the distance of the camera from AB is given by a simple formula depending on the values AB & D′E′, as will be shortly explained. It is therefore proposed that the installation shall include the 6 ~~4~~ fiducial marks A, B, C, D, E, F, each made by cutting with a chisel & then painting in a small cross in a brick or stone that ~~is~~ has been so far buried into the hard level ground, that its surface only is visible. The brick should be disposed lengthways to the camera (if only the one camera that we are describing, be used) on account of ~~the~~ its foreshortening by perspective, and the corresponding arm of the cross should be considerably longer than the other.

Fig 2 is a sketch in rectangular perspective of the general geometry of the problem. N is the camera, raised to a height NM above the ground. whence the various lines of sight proceed, AKLB which rises vertically from the ground is usually called the picture plane, the points of intersection ~~with this plane~~ of the ~~various~~ lines passing from N to the various points in the object, with this plane, forming the picture. Here PQ is the object and a plane is drawn through it parallel to the picture plane. These two planes are connected in the figure, ~~much~~ as the sides of a box are connected by its ends, the connections are put in merely as guides to the eye to show clearly what lines in the sketch are parallel in reality. The line from P to N intersects the picture plane in P', that from Q to N at Q'. Prolonging P'Q' downwards till it meets AB in G, we have in Q'G the representation of QG foreshortened by perspective. The ordinates of Q are QX & XC, where $QX = y$ and $CX = x$ the former being the horizontal line from Q drawn at right angles to AB, whereby X is fixed. R, S, R′S′ are situated in the vertical plane passing through N and C. It is evident from the figure that $RS = PQ$, $R'S' = P'Q'$, and $S'C = QX = y$. Lastly, we have the curious distortion due to perspective, that the line XQ prolonged to infinity appears in the picture as $XQ'V'$; consequently $XQ' = y'$

Fig 3 contains so much of the plan of fig 2 as concerns us

Fig 4 is the elevation of fig 2 as seen

coordinates from C

in section by the vertical plane passing through N and C

The line AB being common both to the objective plane and to the picture serves as a common measure for both

Let the length of NM = V′C be called v; and MC, the horizontal distance of the camera from AB, be called a

The following equations are easily traced

$y : y' = SC : S'C = y + a : v$

$$\text{whence} \quad y = \frac{ay'}{v - y'} \qquad (1)$$

$z : z' = SR : S'R' = y + a : a$

$$\text{whence} \quad z = \frac{vz'}{v - y'} \qquad (2)$$

~~X~~G : $x = y' : v$ and XG : $x' = y : a$

$$\text{whence} \quad x = \frac{vx'}{v - y'} \qquad (3)$$

$\underline{x}$ is however found much more simply by ~~drawing~~ prolonging a line from V' through Q' till it meets AB at X, and then measuring CX.

It has been already mentioned how $\underline{v}$ and $\underline{a}$ can be deduced from the four points A, B, D', E' supposing the latter two to be visible; it will often however happen that the object hides one or both of these, so that the actual picture to be dealt with may not convey the desired information. This is no objection to their use in a preliminary blank picture taken to test the trustworthiness of the installation, and in addition two temporary plumb lines uw should be suspended within the limits of the pictures. Their parallelism in the picture, in addition to the parallelism of AB & D'E'! proves that the real picture has been taken in a plane parallel to the imaginary picture plane ABLK. There are ~~one other~~ now only ~~one~~ two omissions in the catalogue of requirements to test the installation and that is some pictorial proof that the ground within the square is ~~too~~ level. I can think of no other plan than that of propping two builders levels at right angles to one another upon it. ~~Of course a scale of feet & inches might be laid~~ The other omission is evidence of the actual length AB, which would be afforded if a scale of inches were laid on the ground between them. It is almost hopeless yet to expect that

that the decimal scale would be willingly accepted for such purposes as these, otherwise I should certainly propose that AB should be made equal to 2½ metres and the metric scale adopted throughout

It is well to give the formulae for determining $\underline{v}$, and $\underline{a}$, though a draughtsman would not want them. Let $AB = l$, $D'E' = l'$, and for consistency of notation suppose the side of the square, which $= 2$, to be called λ, then the distance

between

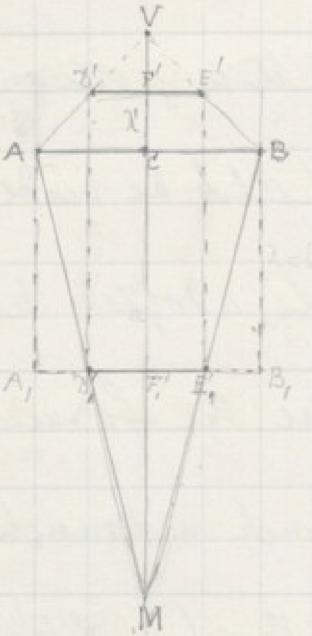


Fig 5

VC = v
CM = a

$lv - l\lambda' = l'v$

$v(l-l') = l\lambda'$

$v = \frac{4\times 2}{4-2} = \frac{4}{2} = 2$

$al' = al - l^2 \quad \therefore \quad a = \frac{l^2}{l-l'}$

a = 8 l' = 2 l = 4

$\lambda' = 2$

$a = \frac{16}{2} = 8$

between AB and DE = CF in fig 2, becoming foreshortened into CF′ in fig 5, will be called λ'. From that fig:

$AB : \delta'E' \doteq VC : VF'$ or $l : l' \doteq v : v-\lambda'$

$$\text{whence} \quad v = \frac{l\lambda'}{l-l'} \qquad (4)$$

Again, to an eye stationed any where in a vertical above M, say at N,

$MC : MF_1' \doteq AB : \delta_1'E_1' = AB : \delta'E'$

or $a : a-l = l : l'$

$$\text{whence} \quad a = \frac{l^2}{l-l'} \qquad (5)$$

Example: let the constants for the installation be

$a = 240$ inches (20 feet), $v = 60$ inches (5 feet)

~~and let~~ the perspective coordinates of P be $x' = 40$, $y' = 10$, $z' = 30$; then $x = 46.7$, $y = 40$, $z = 35$

let those for P_1 be $x_1' = 30$, $y_1' = 8$, $z_1' = 20$; then $x = 33.9$, $y = 31$, $z = 22.6$

From these the horizontal distance between P and P_1 which we will call $\underline{d}$, is easily found, being equal to QQ_1; therefore

$$d = \sqrt{\{(x-x_1)^2 + (y-y_1)^2\}} = \sqrt{\{(12.8)^2 + 9^2\}} = \sqrt{245} = 15.65$$

~~and~~ Then, if D be the actual distance between P & P_1 ~~which we will call D~~ calling

$$D = \sqrt{\{d^2 + (z-z_1)^2\}} = \sqrt{\{245 + (12.4)^2\}} = 15.9$$

Such small calculations as these are rapidly made by the aid of the well known multiplication Tables of Crelle & those of Squares Square Roots &c by Barlow. Some may perhaps prefer an ordinary sliding rule, others, as already said may prefer graphical methods.

anyhow the operation is swift.

In measuring photographs with care, I have found it an excellent plan on two separate occasions of experiment in other lines of inquiry, to prick through the paper at the required points with a fine needle, and to draw lines and make measurements from those points at the back of the paper. The mark made on the photograph itself is practically invisible; that at the back is a beautifully clear & minute circular hole, not easily found without a lens, but when found perfectly distinct & permanent. It is a great advantage then to keep a full record of the work without injuring the photograph. So convenient ~~have I found~~ is this method that I have thought it worth while to have a pricker made, with a microscope. The cross wires are brought over the point by sliding the instrument upon the paper. then the pricker is pressed down.

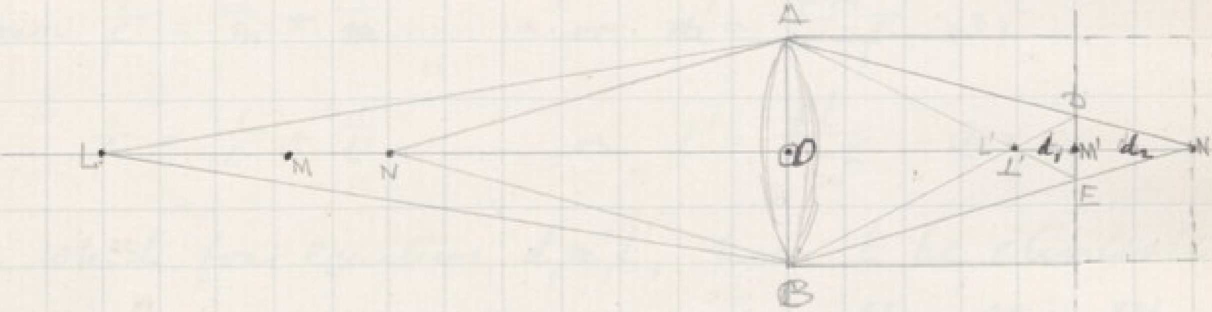
Explain

We now come to the limitations imposed by photography

First the distance of ACB from the camera must be such that any object, such as a horse, standing in the square plot beside it shall be in tolerable focus. This vague term admits of exacter statement by saying that no point in the object shall be represented on the focussing plate by a blur or "circle of confusion" of a stated diameter, say c, which in ordinary cases may be taken at 0.01 inch. If M be a point in the object when situated at a distance OM = m from the centre of the lens, and M' its conjugate focus, then (supposing the lens to be

the image of   at M'
perfect), M will appear as a point on the focussing
the whole of adjusted that
screen when M' falls upon it. Keeping the screen
stationary
in place, but removing the object further off until
in the object
the same point as before ~~in it~~ is situated at L,
appear as a point at
then ~~the~~ its image (which would be ~~sharp~~ ~~at~~ the
conjugate focus L'), becomes spread out) into
around M'   fixed
a circle of confusion (on the focussing screen ~~at~~
(if the position L be so selected that)
~~and~~, when (the radius of that circle ~~becomes~~ = c,
of confusion   diameter
(the images of ~~all~~ objects situated
then ~~any distances of the~~ beyond L cease to
on the screen.   state of things,
be in "tolerable focus". A Similar, mutatis
mutandis occurs on the nearer side of M, when
a point N exists at which the conjugate focus
the image of the point N shall be
N' is so disposed that ~~all objects nearer to~~
just in tolerable focus upon the stationary focussing screen, while points nearer to
the lens than N, cease to be in ~~tolerable~~ focus
so..   on the ~~fixed~~ screen

the problem is
~~Consequently we have~~ now to find the limiting distances OL and ON ~~positions L and N~~ from a knowledge of ~~that~~ ~~O~~M, of c, ~~and~~ of the ~~radius~~ diameter of the aperture of the lens = $\underline{a}$. and of the equivalent focus of the lens = f



(For sake of compactness & clearness the horizontal scale of the diagram is compressed, and the radius of the circle of confusion is made very large)

~~Call~~ Let the distances ON, OM, OL be respectively called n, m, l and ON', OM', OL' be called n', m', l'. AB = a, DE = c.

Then L' lies at the intersection of AE & BD, N' lies at the intersection of lines drawn through AD and BE. Let ~~[illegible]~~ M'L' be called d_1 and M'N' be d_2

To determine L we have

~~that~~ $d_1 = c\,\frac{l'}{a}$ (1)

also $d_1 = m' - l'$ (2)

from the ordinary law of conjugate foci $\frac{1}{f} = \frac{1}{f'} + \frac{1}{f''}$

we have $\frac{1}{f} = \frac{1}{m} + \frac{1}{m'}$ or $m' = \frac{fm}{m-f}$ (3)

and $\frac{1}{f} = \frac{1}{l} + \frac{1}{l'}$ or $l' = \frac{fl}{l-f}$ (4)

from which four equations $d_1 m' l'$, have to be eliminated

$$\frac{c}{a}\cdot\frac{fl}{l-f} = \frac{fm}{m-f} - \frac{fl}{l-f} = \frac{flm - f^2m - flm + f^2l}{(m-f)(l-f)}$$

$$\frac{cl}{a} = \frac{fl - fm}{m-f}$$

$$clm - clf = afl - afm \qquad l(\cancel{af} + cf - cm) = afm$$

$$l = \frac{afm}{af + cf - cm} \qquad (5)$$

which as cf is very small compared to af and cm, may be written

$$l = \frac{afm}{af - cm} \qquad (6)$$

over

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also $d_1 = m' - l'$ (2)

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$$\frac{cl}{a} = \frac{fl - fm}{m-f}$$

$$clm - clf = afl - afm \qquad l(af + cf - cm) = afm$$

$$l = \frac{afm}{af + cf - cm} \qquad (5)$$

which as cf is very small compared to af and cm, may be written

$$l = \frac{afm}{af - cm} \qquad (6)$$

over

f. 12

To determine ~~M~~

$$d_2 = c \cdot \frac{n'}{a} \qquad (7) \qquad d_2 = \frac{c}{a} n'$$

also $d_2 = n' - m' \qquad (8)$

$$m' = \frac{fm}{m-f} \qquad (9)$$

$$n' = \frac{fn}{n-f} \qquad (10)$$

$$\frac{c}{a} \times \frac{fn}{n-f} = \frac{fn}{n-f} - \frac{fm}{m-f} = \frac{fnm - f^2n - fnm + f^2m}{(n-f)\,(m-f)}$$

$$\frac{cn}{a} = \frac{fm - fn}{m-f}$$

$$cnm - cnf = afm - afn$$

$$n(\overset{cm+}{af} - cf) = afm$$

$$n = \frac{afm}{cm + af - cf} \qquad (11)$$ or, omitting cf

$$n = \frac{afm}{af + cm} \qquad (12)$$

f. 13

Thus the two equations are $l = \frac{afm}{af-cm}$; $n = \frac{afm}{af+cm}$

where l = 316 inches = 26 ft 4 in

n = 194 inches = 16 ft 2 in

$n - l$ = 122 in = 10 ft 2 in

or writing $R = \frac{a}{f}$ = intensity

$l = \frac{Rf^2m}{Rf^2 - cm}$

$n = \frac{Rf^2m}{Rf^2 + cm}$

So the whole of the ground of the square is so nearly within focus that no ~~part of~~ point in it produces a circle of confusion of more than $\frac{3}{1000}$ inch in diameter and if the original negative be enlarged $3\frac{1}{3}$ times the greatest circle of confusion would ~~then~~ be about $\frac{1}{100}$ inch in diameter (nearly). ~~In this we~~ It will be found on plotting the figures that ~~the~~ every point within a parallelopiped 10 feet wide and 7 feet high and 9 feet wide between 16 and 25 feet distance is thus in focus ; and if we say ~~portions of~~ 10 feet wide ~~and the part~~ extending between 15 & 25 (we shall be practically safe ~~may be safely ignored in practice~~ the camera being focussed at a point 20 feet off.)

f. 14r

The reduction of scale in a camera with focus of 3 inches, of an object at a distance of 20 feet = 240 inch is $\frac{1}{80}$, that is each inch in the original is represented by $\frac{1}{80}$ inch in the picture, and the body of a horse taken at 66 inches long & of the same length would appear in the photograph as a miniature 0.825 having those dimensions a trifle more than 4/5 of an inch in length (~~nearly~~ or exactly 0.825 inch). If enlarged in the camera 3 times the.

For a reduction to $\frac{1}{60}$ of scale the distance on ground of M must be $60 : 1 :: x : 3$ $x = 180$ inches

The diameter of circle of confusion may be taken = $\frac{1}{4}$ of what in the picture stands for 1 inch that is to $\frac{1}{4 \times 60} = \frac{1}{240}$ inch $= 0.00417$

$c = 0.00417$, $a = 1$, $f = 3.0$, $m = 180$ | $afm = 540$ inch

$af = 3.00$	$af - cm = 2.25$	$l = 240$
$cm = 0.75$	$af + cm = 3.75$	$n = 144$

$l - n = 96$
$= 8$ feet

Hence if side of house that faces the camera ~~is not too near~~ either side of the square, is 3 feet nearer than the further side of the square, it will do.

for l = infinity $af = cm$ $m = \frac{af}{c} = 3 \times 240 = 720$
$= 60$ feet

$3 = \frac{1}{240} \cdot m$, $m = 3 \times 240 =$

(here 1 inch is reduced to $\frac{1}{2}$ millimetre) f. 16r

For reduction to $\frac{1}{50}$th of natural scale we have

~~m = 150 to 3 inch~~ $50 : 1 :: m : 3$ $m = 150 = 12^{ft}\,6^{in}$

take $c = \frac{1}{4} \times \frac{1}{50} = \frac{1}{200} = 0.005$. afm 450 #

$af = 3.00$ $af + cm = 3.75$ $n = 120$ diff $= 80^{in} = 6^{ft}\,8^{in}$

$cm = 0.75$ $af - cm = 2.25$ $l = 200$

$c = \frac{1}{2} \times \frac{1}{50} = \frac{1}{100} = .01$ $afm = 450$

$af = 3.00$ $af + cm = 3.45$ $n = 131$ diff $45 = 3^{ft}\,10^{in}$

$cm = 0.45$ $af - cm = 2.55$ $l = 176$

$m = 150$ inch $= 12^{ft}\,6^{in}$ $l = \frac{afm}{af - cm}$ $n = \frac{afm}{af + cm}$

$c = \frac{1}{2} \times \frac{1}{50} = \frac{1}{100} = .01$, $f = 3.0$ $af = 3.0$ $afm = 450$

$cm = 1.5$ $af + cm = 4.5$ $l = \frac{450}{1.5} = 300^{in} = 25$ feet

$af = 3.0$ $af - cm = 1.5$ $n = \frac{450}{3.0} = 150^{in} = 12^{ft}\,6^{in}$

$c = \frac{1}{3} \times \frac{1}{50} = \frac{1}{150}$ $af = 3.0$ $afm = 450^{in}$

$cm = 1.0$ $af + cm = 4$ $l = 225 = 18$ feet 9

$af = 3.0$ $af - cm = 2$ $n = 112.5 = 9$ feet $4\frac{1}{2}$

$l =$ infinity $af = cm$, $m = \frac{af}{c} = 3 \times 100$ (1) $c = \frac{1}{100}$ $\times 150$ (2) $= \frac{1}{150}$ $\times 200$ (3) $= \frac{1}{200}$

300 450 600

25^{ft} $37^{ft}.6$ 50^{ft}

over

f. 16v

full aperture
my portrait-lens equiv. focus = 2.76

clear angle of view   width = 0.6 × distance = 31° 24′

by length of screen to use
with 1/2 quarter plates

if 1/60 for reindeer vertically
1/2.5 for foreshorten $\frac{1}{60 \times 2.5} = \frac{1}{150}$ horizontally

shrinkage for 1 inch increased distance, at 15 ft = 180 inch, of height of 66 in.. 1:66::x:180 x = 2.18

horizontal equivalent $\frac{2.18}{150} = \frac{1}{69}$

(more than $\frac{1}{3}$ mm.)

2.18 : 150 = 1 : x

and &c = $\frac{1}{200}$

if accept $\frac{1}{50}$ for reduction, which means 12 ft 6 in for distance with lens f = 3 inches

then an error of 2.27 inch (say 2 1/4) will foreshorten the height of withers, taken at 66 inch (= 16 1/2 hands) by 1 inch

$\frac{2.27}{50}$ = 0.0454 inch ~~on by~~ with the ~~picture~~ reduction = .00022   .015

but the reduction of ground is foreshortened $\frac{1}{3}$ so 1 in is represented by $\frac{1}{150} \times \frac{2.27}{150} = .015$

so error in picture of ground of 0.0151 or $\frac{1}{66}$ inch will
cause an error of 1 inch in calculating height of withers

$\frac{9750}{66}$ = 148 nearly

2.27 : 50 = 1 : x   15/1000 (66   66) 9750 (147.73

50) 2.27 (.0454   Ans. 0.0454

or writing $R = \frac{a}{f}$ $\quad l = \frac{afm}{af-cm}, \; n = \frac{afm}{af+cm}$

$\longrightarrow \; l = \frac{Rf^2m}{Rf^2-cm}, \; n = \frac{Rf^2m}{Rf^2+cm}$

$m = 10^{ft} = 120^{in}$ reduction is $\frac{3}{120} = \frac{1}{40}$ $\quad c = 0.01 \quad f = 3 \quad a = 1$

$afm = 360 \quad cm = 1.2$ ~~foca...~~ $af = 3$

$af = 3.0 \quad af - cm = 1.8 \quad l = 200 = 16^{ft}8 \quad$ ~~dist~~ $125 = 10^{ft}5$

$cm = 1.2 \quad af + cm = 4.8 \quad n = 75 = 6.3$

$afm = 360 \qquad c = \frac{1}{150}$

$af = 3.0 \quad af - cm = 2.2 \quad l = \cancel{35}\ 164$

$cm = 0.8 \quad af + cm = 3.8 \quad n = 95$

Width of plot in which circle of confusion has diameter not exceeding C

Scale of object Reduced to	$\frac{a}{f} = R$ R / C	0.4		0.3		0.2		Distance of object when without sharp focus $f = 3$ inches	with my lens $f = 2.76$
	C	$\frac{1}{100}$	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{200}$	$\frac{1}{100}$	$\frac{1}{200}$		
$\frac{1}{40}$	width of plot	90 in $7^{ft}.6$ 180 in	103 $3^{ft}.5$ 144	83 $11^{ft}.1$ 216	98 ft 4.8 154	72 ft 24.– 360	90 ft 7–6 180	10 feet	ft 9.2
$\frac{1}{50}$	width of plot	106 13.– 262	115 6.3 190	97 20.– 337	117 7.7 208	82 68.2 900	106 12.8 258	$12^{ft}.6^{in}$	11.6
$\frac{1}{60}$	width of plot	120 20.– 360	144 8.– 240	108 36.– 540	135 12.1 280	90 infinite ∞	120 20.– 360	$15^{ft}.$–	13.9

nearer limit of plot $= n = \frac{Rf^2m}{Rf^2+cm}$

farther " $= l = \frac{Rf^2m}{Rf^2-cm}$