Delbouef, Joseph Rémi Leopold

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Dr J. Delboeuf
Etudes psychophysiques (Bruxelles 1873
F. Hayez)
extraits du tome XXIII des memoires couronnes et autres memoires publiés par l'academie royale de Belgique. 1873

Delboeuf
Law of Sensation & fatigue
1873.

UNIVERSITY COLLEGE LONDON
GALTON PAPERS
2/12/10

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BOURNEMOUTH.

4. The impossibility of communicating to others the exact character of our sensations. — There is a barrier between the experimenter & his subject. — Also there exists no
5 quantitative scale of sensations. We want to be able to construct a double scale; on the one side a scale of increments of external physical influences & on the other, the corresponding internal psychical effect. It is evident that these do not follow the same law. A great increase of exterior action does not produce a corresponding increase of interior action. thus a concert of many hundred performers is not much louder than a much smaller one. — Again when the excitation is extreme the sensation changes its character & becomes painful.
6 This question was touched on by Euler Hebart Bernoulli Laplace Buffon — & by Arago Pogson — especially Masson for sight but Weber was the first who in his "Handwörterbuch der Physiologie — Tastsinn" first formulated a law & Fechner coordinated in his Elements of Psychophysics 1860 all the works of his contemporaries & his own researches.
7. Definitions the "organic modification" or "impression" is the external fact; we may admit that this is proportional to the intensity of the external agent (? as to this) & that we may substitute the measure of the latter for it. He calls this, (whether the organic modification or the acting cause)

Why cannot a 4th case be tried, of equal differences.
i.e. A as much heavier than B, as B is than C. ?

the Excitant ("Excitation") and the corresponding internal sentiment, the ~~sensation~~ sensation, whether it be a special sense, or a general one, as that of fatigue.

7) Fechner's 3 methods; the 1st, that of just perceptible differences being a special case of the 2nd, that of ~~true~~ right & wrong estimates. He shews that

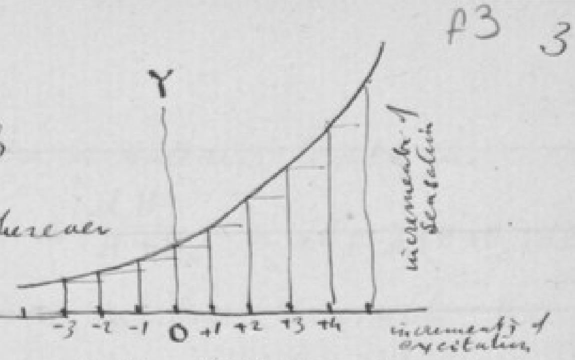
10.) the 1st case is very undependable & that the 2nd is far better though it exacts much time & patience — all three methods concur in giving results, which within certain limits are expressed by Weber under the law "Every constant increment of a sensation corresponds to an increment of excitation proportionate to the total amount of excitation"

11) ~~i.e. $\Delta s \propto$~~ $ds = k\,\frac{d\epsilon}{\epsilon}$. The ratio of $d\epsilon$ to ϵ is for pressure $\frac{1}{3}$; temperature $\frac{1}{3}$; loudness of sound $\frac{1}{3}$; light $\frac{1}{100}$; horizontal distances, perpendicular to the visual axis $\frac{1}{50}$ [These numbers are taken from Wundt. Vorlesungen über Menschen und Thierseele Leipzig 1863, p 98]

13. by taking $S = 0$ when $\epsilon_0 = 0$, and if ϵ_0 is taken as 1, we have $S = k \log \epsilon$. but this formula raises both mathematical and physical difficulties.

a, mathematical. If $\epsilon_0 = 1$ at the same time that $S = 0$ then for a value of ϵ less than ϵ, ~~the~~ S must be negative & for $\epsilon = 0$ the S must be an infinite negative. [Wundt op. cit. criticises in the same way]

1(4) The curve is infinite at both ends consequently the -ve infinity must exist wherever the sensation O is placed, corresponding to a single positive excitation. Fechner says that unfelt sensation, so to speak exists & that the curve deals not on the positive side with felt sensations – just as logarithms begin with 0 for 1. The author won't acknowledge the possibility of an analogy between physical facts

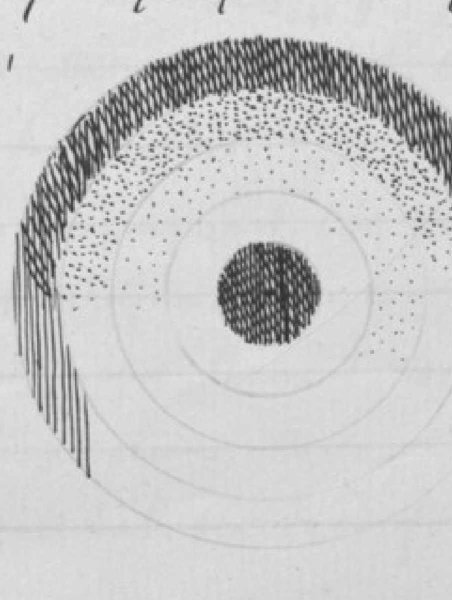


16 & such abstract conceptions as logarithms.

19 2 Physical difficulties. The formula gives for two sensations

$$S - S' = k\,\frac{\log E}{\log E'}$$

or the difference between two sensations is constant if the ratio between the excitations is constant; but experience does not confirm this except between limits – as daylight closes we can distinguish hardly anything – similarly in very bright light. Make concentric rings of which the middle appears exactly intermediate in tint in a certain light, diminish the light & it becomes relatively darker & vice versâ



20 Helmholtz criticism - as there is interior light H_0, the formula must have the form $dE = A\frac{dH}{H+H_0}$ or $dH = \frac{1}{A}(H+H_0)dE$
Hence the increase of light must be greater in order to be visible than it w^d be if H_0 were $=0$. Again the limits of illumination are very narrow at which slight variations of shading become apparent. Certain photos of snow upon glass ~~shad~~ shadings invisible in ordinary light, clearly seen at a moderately bright light & again invisible in a very bright one, hence A in the above formula is not a constant but some function of H. It is one that causes sensation to reach a maximum which it cannot exceed even when E increases, $\left(\frac{dE}{dH}\right.$ ~~that is~~ sensibly little changed for moderate values of H & be 0 when H is infinitely large
The simplest of such functions is $A = \frac{a}{b+H}$ where b is very great
put then $dE = \frac{a.dH}{(b+H)(H+H_0)}$, whence $E = \frac{a}{b-H_0}\log\left[\frac{H_0+H}{b+H}\right]+C$
It is by some such formula as this that we may hope to completely represent the phenomena. — So far Helmholtz.

24. Leboeuf continues - if a man can only just lift 100 kilos the addition of $\frac{1}{2}$ kilo will ~~make~~ impossibility — If he can throw a stone at the utmost 100 metres he cannot throw it 101. Therefore Weber's law does not hold in these extreme cases. Again, one measures sensations by an internal standard of reference

24) which no doubt varies, but still is employed by us. We say the day is dull or bright &c. The unit of reference is derived out of the very nature of our sensibility. It results, as we shall see, from the stability necessary for the normal accomplishment of our functions.

27 Theoretical part.

(1) Intensity of sensation depends partly on intensity of excitant & partly on the mass of sensibility at the time – The excitation withdraws part of the sensibility & the next excitation affects, so to speak, a new individual

(2) There is a residuum of ~~force~~ or sensibility c that excitation cannot exhaust; similarly of force v that the will cannot exhaust. Hence the disposible quantity of either = the total quantity less this residuum. If m be the total of sensibility and force, the disposible quantity $= m - v - c$

c is the sensation due to the existing conditions of the living body, animal heat in the case of temperature – weight of limbs – light in retina &c. – If δ = objective excitation, the total impression is $c + \delta$. c is not consciously felt; 29 as soon as any excitation is added to it, it is felt.

30.) But c may be abnormally heightened, as in fever, & give rise to sensations. But c being usually pretty constant affords us a standard by which to measure the intensity of our sensations.

33 Call M−v the force disposable for work, m; δ the expenditure of force & f the sense of fatigue corresponding to δ. Now f grows with the amount of labor so we may say hypothetically that it grows directly as dδ and inversely as the amount of disposible force hence $df = k\frac{d\delta}{M-v-c}$, whence by integration $f = k \log \frac{1}{m-\delta} + x$

To determine x; suppose when $\delta=0$ that $f=0$ then $x=\log m$ hence $f = k \log \frac{m}{m-\delta}$. Now to get rid of k, suppose when $\delta=1$ that $f=1$ whence ~~f~~ $k = \frac{1}{\log \frac{m}{m-1}}$

34. The formula for sensation is this

increment of S varies as the $\frac{\text{~~particular~~ increment of objective excitation}}{\text{total excitation}} = k\frac{d\delta}{c+\delta}$

whence integrating as before & if we suppose when $\delta=0$ $S=0$, $S = k' \log \frac{c+\delta}{c}$ & $k' = \frac{1}{\log \frac{c+1}{c}}$

Lastly in each formula using the unit of excitation the quantity that renders $k=1$, is in the f formula $1k = m\frac{e-1}{e}$ & in the S formula $1S = c(e-1)$

we have

$$f = \log \frac{m}{m-\delta} \quad (A)$$
$$S = \log \frac{c+\delta}{m} \quad (B)$$

these become 0 only when $\delta=0$ and can never be −ve

37 . For Equal increments of fatigue, the increments of expenditure decrease in a geometric progression whose ratio is e^{f} e is the base of naperian $\log^s$ = 2.718..

38 For Equal increments of sensation, the increments of excitation increase in a geometrical progression whose ratio is e^{s}

{In the f series δ_{n-1} is greater than $\frac{\delta_n + \delta_{n-2}}{2}$, or the arithmetic mean;
s .. - - less . - - - - - - - - }

39 Leboeuf's law differs notably from Weber's thus:—

S_0	S	$2S$	$3S$	$4S$	–	Weber
ϵ_0	ϵn	ϵn^2	ϵn^3	ϵn^4	–	
$S+a$	$S+2a$	$S+3a$	$S+4a$	– –		Leboeuf
$\epsilon+n$	$\epsilon+n^2$	$\epsilon+n^3$	$\epsilon+n^4$	– –		

40. The formulae for f & s are

$$f = \frac{\log \delta_n - \delta_{n-1}}{\delta_{n+1} - \delta_n} \qquad s = \log \frac{\delta_{n+1} - \delta_n}{\delta_n - \delta_{n-1}}$$

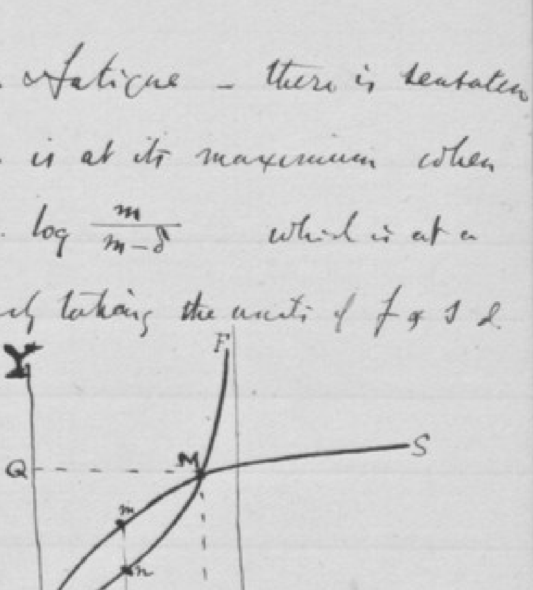
reciprocal in their notation. but) because in f, δ_n is greater than δ_{n-1}, & in s it is less the numerators are in both cases greater than the denominators (i.e. for equal increments of fatigue the successive bits of work done decrease (see p 33) & for equal increments of sensation the successive increments of objective excitation increase)

42. The normal range of sensibility is between $\delta = 0$ and $\delta = m - c$, the maximum sensibility is at $\frac{m-c}{2}$, below this the effect of feeble excitation becomes more & more obvious ; above it, fatigue sets in. — All excitation

42) produces a double effect – sensation & fatigue – there is sensation so long as $S-f$ is positive, & sensation is at its maximum when $s-f$ is a maximum $\quad s-f = k.\log\frac{m}{m-\delta}$ which is at a maximum for $\delta = \frac{k'm-kc}{k+k'}$, or by judiciously taking the units of f & s &

43 we get $\delta = \frac{m-c}{2}$

44



OS the curve of sensation; $s = k'.\log\frac{c+\delta}{c}$

OF the curve of fatigue; $f = k\log\frac{m}{m-\delta}$

they both give infinite values but ~~the~~ f is infinite for a finite value of δ $(=m)$ and S is infinite for an infinite value of δ. The two curves cross at M, which in the special case where m-c is taken as the limit of excitation corresponding to the unity of fatigue & sensation is at M the corner of the square here $OP = m-c = 1$ and $MP = f_1 = s_1 = 1$. mn is the maximum interval between the two curves & $Op = \frac{OP}{2}$

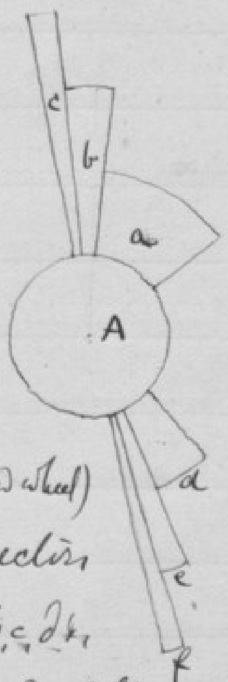
46. The normal action of sensibility extends from O to M.

M may be regarded as constant for short periods under precautions so as to be the same in $M-\delta$, $M-\delta-\delta'$, $M-\delta-\delta''-\delta'''$, &c. It can be transferred to any organ so that all or much of our energy is temporarily concentrated there. M may be considered as the store contained in a

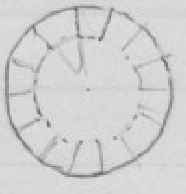
49) large reservoir, fed by an intermittent source or continually flowing through openings into small vases which allow the superabundant supply to overflow. These openings are not of a constant size, but may be varied, ~~so as to~~ up to a certain point, at which some refuse to receive more, others burst.

50 Experimental Part. (made between 1865-6)

The method of experiment was suggested to Leboeuf by Plateau namely that of revolving sectors



Two discs ~~A circle~~ A, 5 centim. in radius, cut out of white card & admitting of being covered when desired by a disc of black velvet of the same size. These card discs are glued on opposite faces of a third disc cut into the form of a star (? toothed wheel)



having openings in which sectors could be inserted, such as a, b, c, d &c.

These sectors belong to circles of 3 different radii & there was a sufficient series of them to produce every arc between 1° & 360°

The paper must have a uniformly white surface – He always used Bristol card covered with "papier vélin".

He began by trying a plan of Plateau's to obtain a tint

52) intermediate between absolute black & various whites. but the absolute black was impracticable. He gives a plan of the apparatus used.

53. First experiments to verify ~~[illegible]~~ $s = \log \frac{c+\delta}{c}$

He varied the brightness of the interior ring until the brightness of the middle ring seemed exactly intermediate between that of the outer & the inner. Then a table of experiments

No. of observ.	angle of sector: external ring	middle ring	interior ring: calculated for $c = 0.05$	$c = 0.12$	numbers obtained experimentally					min	max	mean of min & max	general mean
1	9°	47°	237°	242°.2	287	249	272	205	177	177°	287°	232°	237°.4
2	13°	27°	55°.5	55°.9	53°	54°	54	56°	53	53°	56°	55°.5	54°.4
&c													

He had much trouble owing to time lost in changing the sectors during which the observer was fatigued or the light changed or some accident happened to the revolving apparatus; 3 or 4 sets had to be rejected for each that was retained. In practice the tints were begun alternately much too light or too dark & changed until the judgement was satisfied. The judgement was given

56) at first sight, it was not found advisable to look too long or the judgement changed (f fatigue) Sometimes one single adjustment took ½ hour before

57) the judgement was satisfied. The formulæ ~~for~~ for δ'' are

$$\delta'' = \frac{\delta'^2 - cd + 2c\delta'}{c+d}\text{; or, when } c = \tfrac{1}{2},\quad \delta'' = \frac{2\delta'\{\delta'+1\} - \delta}{2\delta+1}$$

59. He examines & discusses the results & finds them very conformable to his theory

6b). Another table of similar experiences – also in a dull day

62) A third table of exper^n during candle light. – This is a troublesome source of light because objects in the room throw various sheens of light & the judgement is disturbed.

63) A fourth table of experiments on 6 observers; deducing a general mean, he obtains the following excellent results

66)														
observed	239.6	55.2	102.3	129.6	(241.5)	169.5	191.7	59.9	117.	155.7	190	94.1	124	180
calculated	237	55.5	98.3	127	236	169.7	193.	58.7	117.4	151.6	196	97.4	119.5	175.5

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66) Experiments to shew directly that c exists & is positive

Clearly the formula (proved above) compels this view as if $c=0$, $S = \log \frac{c+\delta}{c}$ w^d be infinite & equally so if $\delta = c$ in amount, irrespectively of sign.

To find the conditions that c is 0, infinite, negative or positive, from the equation $c = \frac{\delta'^2 - \delta\delta''}{\delta + \delta'' - 2\delta'}$

if $c = 0$, $\delta'^2 = \delta\delta''$; is δ' is the geometric mean of δ & δ''

if $c = \frac{1}{0}$, $2\delta' = \delta + \delta''$; is δ' is the arithmetic mean of δ & δ''

the previous experiments absolutely refute these hypotheses

if c is less than 0, we must have (1) both δ'^2 greater than $\delta\delta''$ & $2\delta'$ greater than $\delta + \delta''$ or (2) vice versa & these are not true

if c is greater than 0 we must have (1) both δ'^2 greater than δ'' & $2\delta'$ less than $\delta + \delta''$ or (2) vice versa of these (1) is theoretically impossible so (2) is the only possibility left. – In other f 125 (12

words that c may be positive δ' must be greater than the arithmetic mean of δ & δ''' & less than the geometric mean between the

68) same quantities (greater than $\frac{\delta+\delta'''}{2}$ and less than $\sqrt{\delta\delta'''}$)

70. First Table of experiments to shew that when with a candle 25 centimetres off δ being = 13, δ' 41, and δ'' = 127.8 that δ'' varies in value as the candle is removed to the distances $0^m.50$. 1^m 2^m 3^m & 4^m & the values of δ'' become 98.5, 94.5, 91.2, 88.7, 88.5. These experiments were rather rude & Leboeuf regrets he was unable to repeat them with more care, to see if they wd give good values for c. There are difficulties due to contrast of each ring with its neighbours so that the outside of each ring looks brighter on the outside, darker on the inside. the inner ring contrasts on both sides with a darker colour (black on the inside). Again he says, that the brightness of a ring decreases as the eye is removed further from it (?) He thinks he sees why, but cannot verify the fact even

75 Second Table of experiments for the same purpose, more carefully made with (1) a candle at 25 centim. (2) in in a dull day (3) a grey day (4) bright day in a room, (5) bright day out of doors.

It results that given 3 graduated zones, a diminution of f12v

δ'' is greater than δ' & $s''-s' = \log \dfrac{c+\delta''}{c+\delta'} = k$ suppose
which is greater than 1

Suppose δ' becomes $\delta'-x$ & δ'' becomes $\delta''-y$ & let k remain constant

(1) then $\dfrac{c+\delta''}{c+\delta'} = \dfrac{c+\delta''-y}{c+\delta'-x} = k$;

$\cancel{c+\delta''-y = kc+k\delta''-kx}$ or $\left\{ \begin{array}{l} c+\delta'' = kc + k\delta' \\ c+\delta''-y = kc + k\delta' - kx \end{array} \right\}$.

$$\therefore -y = -kx \,,$$

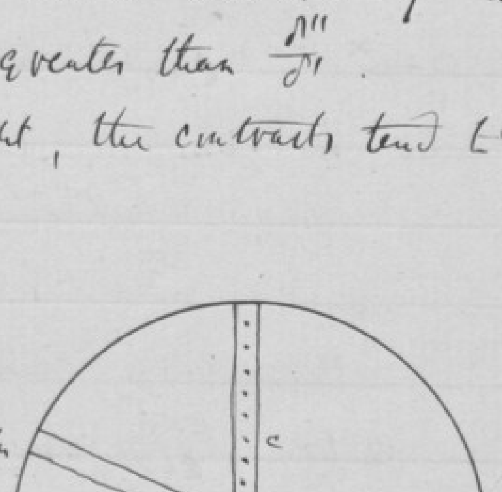
$$\frac{y}{x} = k \quad \text{or } y \text{ is greater than } x$$

now in (1) the terms of $\dfrac{c+\delta''}{c+\delta'}$ are greater than those in the other half of the Equation $\dfrac{c+\delta''-y}{c+\delta'-x}$
(Each of the fractions being greater than 1)
Hence if we subtract the same quantity c from both the terms of both the fractions, the first will become smaller than the second or $\dfrac{\delta''-y}{\delta'-x}$ will be greater than $\dfrac{\delta''}{\delta'}$. In other words, in order to maintain k constant the ratio of the feebler excitations ($\delta''-y : \delta'-x$) must become greater than that of the less feeble ones, ($\delta'' : \delta'$)

75) light causes a greater contrast between the 2 exterior zones. This is not an absolute increase of contrast but relation to that between the 2 inner zones.

The smaller the excitations, the more the ratio between them should increase in order that the differences between the
77.) corresponding sensations should remain constant; hence when when the light is very faint we cannot distinguish tints thus if δ' becomes $\delta'-x$ and δ''' becomes $\delta'''-y$ we find theoretically that $\frac{\delta''-y}{\delta'-x}$ is greater than $\frac{\delta''}{\delta'}$.
Again under too strong a light, the contrasts tend to efface themselves

Experiments on this:-
A disc (10 centim: radius) on which bits of circular lines each 4 millimetres are traced at A at successive distances of 1. centim:. There are 3 moveable arms, B, C, D 4 mm broad able to cover one another.



B is blank. C has marks 1 mm long, D has marks 2 mm long. By superimposing these variously we get every variety of length of f14 14

line (when the disc is whirled) between 1, 2; 3 — 7 mms.
The total circumference of a circle drawn at 1 centim: = 10 mm radius = 62.852 mm; – call it a. Then those at 2, 3 &c centim. have total circumference of 2a 3a &c. & the intensities of the black rings of it alone (when the disc is whirled) are as $\frac{4}{a}$ $\frac{4}{2a}$ $\frac{4}{3a}$ &c
Experiments were made with a candle, moving it to various distances, to learn those at which the ~~successive~~ black rings successively come into view. ~~The final result~~
~~82) is a table of mean distances of invisibility of the rings.~~ There
81) proves to be 40 available rings of different intensities and not one of the ~~first~~ 26 the faintest of these was visible when the candle was at its nearest (1 metre), leaving 14 for experiment. It was evident that as the light became fainter the fainter rings successively disappeared, but the results are not finally worked out.

83.) c is calculated on the formula $c = \frac{\delta'^2 - \delta''\delta'''}{\delta'' + \delta''' - 2\delta'}$
for $\delta'' = 127.8$ c is found $= 0.53$ & for $\delta'' = 123.3$ it $= 1.7$ &c &c, giving a mean result of $c = 0.75$ – but the method wants precision

c varies in different persons — in same person at different times — & is constant for a sufficient period to carry on a set of experiments.

84. He tried three rings of values 13 41 & 100 & shifted the candles until the middle zone appeared exactly intermediate

91. It seems that c may vary between limits one of which is ten times as great as the other

Construction of a scale of sensations

He makes a spiral figure

$\omega = 360^\circ$ for $r = 14$ mms

$\omega = 0^\circ$ for $r = 154$ mms & he takes $c = \frac{1}{2}$

whence the formula for the spiral is $\omega = 695.7\, e^{-0.047 r} - \frac{1}{2}$

[mem $\log\left(695.7\, e^{-0.047 r}\right) = \log 695.7 - 0.047\, r \log e$]

Hence

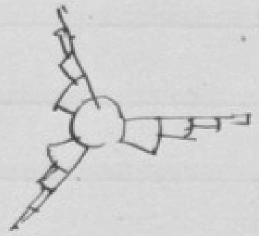
94)

Order of sensations	Values of r in millimetres	Values of ω in degrees & decimals
0	154	0
I	144	0.30
II	134	0.79
-	- -	
-		
XIII	24	224.9
XIV	14	360
XV	4	567.1

cutting out a figure on these data & spinning it, we
get a beautiful effect of a gradually diminishing tint

97). another table giving $r = 0$, $\omega = 360$ & $s = 0$ $r = 150$ mm

It is best to divide the figure into
2 or 3 parts that the rate of
rotation be diminished $\frac{1}{2}$ or $\frac{1}{3}\omega$



a very slight error in cutting out
conspicuously disarranges the gradation of tints
This is the verification à posteriori of $s = \log \frac{c+d}{c}$

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101) Experiments on fatigue

These are difficult. 2 plans; - one to increase work by successive increments, & to note the corresponding fatigue – this is scarcely practicable – the other, to produce successive increments of fatigue & to note the corresponding increments of work done –

He takes a dynamometer (Regnier) & makes the operator work at it, pulling it to the utmost, time after time at regular intervals & noting the work done. The operation must
103) be perfectly rhythmic, the operator must be practised at

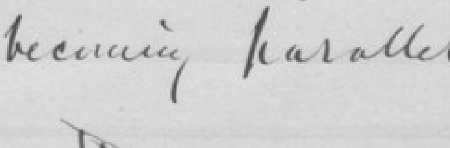
the work - for example their hands must not be blistered. & it is necessary to proceed with some rapidity, that the operator be not fatigued by one portion & that he may not recuperate too much in the intervals. Besides this there is some difficulty about maximum effect. a spurt can always be put on.

Table of an Ardennes woman's work. She pulls with strange uniformity, & goes on for an indefinite time. Tables of 4 others, very different in this respect. But all agree in this that after a certain limit, the series all become uniform [Ideally, they arrive at a state in which the supply just balances the expense.] A high bred animal can exhaust his power in a few supreme efforts.] There is great difficulty about coordinating different series to obtain mean results

He works with sets of 5 - at same time of day, for after meals the series are different to those before - 10 minutes between each series. The 5 pulls he looks upon as
110 successive increments of fatigue & he anticipates the work done to diminish in a geometrical ratio.

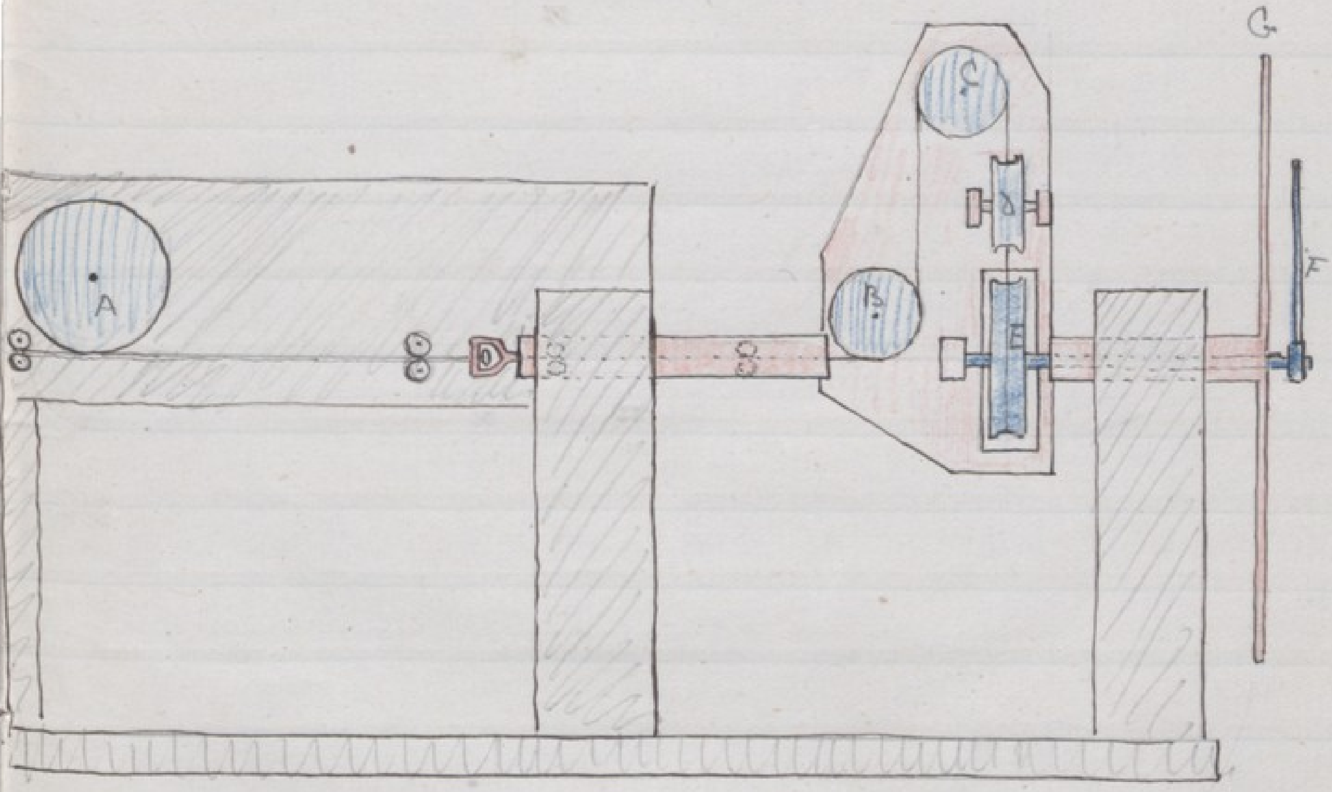
111 Gives a table of such experiments to verify the formula $f = \frac{m}{m-\delta}$ & he thinks on the whole that it does.

[refers to Kronecker arbeiten aus der Physiologischen Anstalt zu Leipzig. Leipzig 1872 Über die Ermüdung &c der quergestreiften Muskeln?] Then he says, interprets fatigue as loss of power, whereas Delboeuf means the sentiment of fatigue. Still he (Delboeuf) thinks that these two go precisely together, indeed he postulates p 7. that the sentiment of fatigue is proportionate to the ~~work done~~ force expended. Kronecker says that the curve of fatigue of a muscle overcharged & irritated at intervals by blows of equal intensity is a straight line — that at length inclines to the axis and ends by becoming parallel to it

The ordinates are the ~~spaces~~ lifts 

marked by a myograph, 1, 2, 3, &c between the successive moments of irritation]

End



A is the primum mobile:—

A second wheel A' on the same shaft as A, communicates through wheels B'C' & D', to E', facing the operator, so that he sees the ∠ between F & G by F' & G', G' being stationary

In the drawing, insufficient length has been allowed for the to-&-fro motion. In each case it is a wrapping connector attached to a rod moving to & fro between pulley guides.

Delboeuf

Sensation x fatigue