differences. As has been mentioned the moulting ♂♂ are smaller than the ♀♀. The very marked differences present in the posterior part of the body of ♂♂ and ♀♀, also occur in the moulting ♂♂ and ♀♀. In both the cuticular tail-point is thrown off together with the old cuticle. In preparations of the moulting ♀, we see the long tail, somewhat rounded at its extremity, beneath the old cuticle; the distance between the anus and the extremity of the tail is rather considerable here. In the moulting ♂ however, this distance is small and here the posterior part of the body shows already all phenomena described in detail by RAILLIET 1883, EHLERS 1899, and JERKE 1900.

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Utrecht, May 1920.

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ABBREVIATIONS.

an. = anal opening.
c.o. = mouth-cavity.
cut. = imaginal cuticle.
l.cut. = larval cuticle.
c.p. = larval cuticular point.
ent. = intestine.
l.c. = lateral cells.
m. = margin of mouth.
musc. = muscles of the body-wall.
m.r. = rectal muscles.
n. = nerve-ring.
c.ph. = corpus pharyngis.
i.ph. = isthmus pharyngis.
b.ph. = bulbus pharyngis.
c.ph.w. = wall of the corpus pharyngis.
r. = rectum.
r.g. = rectal glands,
v. = valves of the bulbus pharyngis.

Physics. — *"The Limit of Sensitiveness of the String-galvanometer".* (2d communication). By Prof. J. K. A. WERTHEIM SALOMONSON.

(Communicated at the meeting of June 26, 1920).

In the meeting of June 26th 1918 I read a paper in which I showed, that the sensitiveness of the Einthoven-galvanometer was limited by the elasticity of the material of the string. At the same time I stated that the actual limit was never reached. The theoretical liminal value in every case was much smaller than the actually observed value, except with very thick strings. There seems to exist a simple cause for this fact. It is not only the elasticity of the perfectly relaxed string that causes the deviated string to resume its original form and position of rest after stopping the current through it, but also gravity. As the exact form of a deviating totally slackened string is not the same in every case, and cannot be exactly represented by a formula, it is only possible to approximately calculate the influence of gravity. We can do this in the simplest way by assuming that the string is suspended in a homogeneous field of H gausses; that it bends in the point of suspension without any resistance or friction; that the lower current bearing connection is equally free from resistance, friction and mass; and finally that the string is straight and rigid and does not change its form. If the length of the string be l, the diameter d, the density of its material γ and the gravitational constant g, the string is acted upon by a force $p = {}^1/_4\, \pi\, d^2\, l \gamma g$. As soon as the wire be deflected, its middle part being moved over a distance h, the force pulling the string back to its original position is

$$p_1 = \tfrac{1}{4}\, \pi\, d^2\, l\, \gamma\, g \frac{2h}{l} = \tfrac{1}{2}\, \pi\, d^2\, \gamma\, h\, g \quad . \quad . \quad . \quad (1)$$

If this force is in equilibrium with the current i, we may put:

$$H\, l = \tfrac{1}{2}\, \pi\, d^2\, \gamma\, h\, g$$

or

$$h = \frac{H_i\, l}{\tfrac{1}{2}\, \pi\, d^2\, \gamma\, g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

In my former communication I found the formula:

$$h = \frac{H_i\, l^4}{6\, \pi\, E\, d^4} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

for the deflection of the middle part of the totally relaxed string, E being the elasticity modulus.

Comparing the expressions 2) and 3) we see that variation of the diameter d — and as a matter of fact also of the length l — appears to have another influence with relation to the weight of the string than with relation to its elasticity. Halving the diameter should cause the sensitiveness to increase 4 times according to 2) and 16 times according to 3). The significance of this is, that the two formulas should be combined in some way. Also we see that with thick strings the sensitiveness is principally limited by the elasticity of the material, whereas with very thin strings elasticity has little or no influence at all but it is the weight that counts. Finally there should be for any material a definite length and diameter with which the limiting influence of weight and elasticity are equal. This critical diameter can easily be calculated by equating 2) and 3). We find then:

$$d = \sqrt{\frac{l^3 \gamma g}{12 E}} \quad \ldots \ldots \ldots \quad (4)$$

With this formula table I can be calculated giving the critical value of the diameter (with a length of 10 and 5.6 centimeters) with which the influence of weight equals that of the elasticity.

TABLE I.

	$\frac{E}{98.1.10^6}$	γ	d with $l = 1.0$ c.m.	d with $l = 5.6$ c.m.
Copper	11000	8.9	8.2 μ	3.4 μ
Silver	7500	10.5	10.8 »	4.5 »
Gold	7500	19.5	14.7 »	6.1 »
Aluminium	6750	2.7	4.6 »	1.9 »
Platinum	16500	21.4	10.3 »	4.3 »
Silvered quartz	(6000)	(5.46)	8.7 »	3.6 »

The value for E used for silvered quartz does not take the silvering into account, which anyhow cannot possibly be of much importance. The figure given for the density is calculated from the weight divided by the volume in case of a silvering of a thickness which gives the highest possible normal sensitiveness (v. Theoretisches und Praktisches Zum Saitengalvanometer, Pflügers's Archiv. f. Physiologie V. 158 p, 107 1914).

With a silver wire of 10 cm. length and of a diameter of more than 10.8 μ the sensitiveness is mainly limited by the elasticity; with silver wires of the same length but thinner than 10.8 μ, the weight of the wire is the most serious obstacle to increasing the sensitiveness of the instrument. With a wire of 21.6 μ the elasticity is 4 times more important as a limiting factor than gravity.

If the influence of the two limiting factors is taken together, we find for the deflection of the middle part of the string:

$$h = \frac{H_i\, l}{{}^1/_2\, \pi\, d^2 \gamma g + \frac{6 \pi d^4 E}{l^3}} \quad \ldots \ldots \quad (5)$$

if the string be totally relaxed and fixed on the support without any longitudinal or torsional tension.

With this formula we can calculate the next table giving the deflection of a 10 cm. string of 1 μ in a field of 10.000 Gausses with a current of 10^{-12} Ampere and an enlargement of 1000 times.

TABLE II.

Copper	0.72 mm
Silver	0.62 »
Gold	0.34 »
Aluminium	2.27 »
Platinum	0.33 »
Silvered quartz	1.17 »

In the same way I find for an aluminium string of 2 μ and 56 mm. length in a field of 18000 gausses a thêoretical deflection of .57 mm., the magnification being 1000 fold. In my former communication I stated that such a string had given me a deflection of .40 mm. If we had taken the elasticity as the limiting agent we ought to have expected a deflection of 1.20 mm.

Doubtless we get a better approximation for the liminal sensitiveness of the string galvanometer by considering the influence of the weight of the string without neglecting its elasticity.