46. Similarly we have,

(a). $6\,A\,.\,p\,.\,S\,(q\,K\,q_1)\,S\,(r\,K\,r_1) =$ *line in space* (p, q, r) *perpendicular to plane* (q_1, r_1).

This line is therefore $-\,A_1\,.\,q_1\,.\,K r_1\,.\,[\,A\,.\,p\,.\,K q\,.\,r\,]_1$, the constant factor being determined by putting $p, q, r = i, j, k$, $q_1, r_1 = j, k$. This becomes, to the factor $S\,r\,K\,r_1$, the line of *44* (*a*) when r_1 is perpendicular to the plane (p, q)

(b). $6\,A\,.\,S(\,p\,K p_1\,)\,S(\,q\,K q_1\,)\,S(\,r\,K r_1\,)$

$= S\,.\,A\,.\,p\,.\,K q\,.\,r\,K\,.\,A_1\,.\,p_1\,.\,K q_1\,.\,r_1$

$=$ product of volumes times cosine of angle between the spaces of the parallelopipeds (p, q, r), (p_1, q_1, r_1)

(c). $24\,A\,.\,p\,S(q\,K\,q_1)\,S\,(r\,K r_1)\,S(s\,K\,s_1) =$ *line perpendicular* to $(p_1, q_1, r_1) = A_1\,p_1\,.\,K q_1\,.\,r_1\,.\,S p'\,K p$.

This becomes, to the factor $S\,(s\,K s_1)$, the line (a) when $s_1 \perp (p, q, r)$.

(d). $24\,A\,.\,S(p\,K p_1)\,S(q\,K q_1)\,S(r\,K r_1),\,S(s\,K s_1)$

$= S\,p'\,K\,p\,.\,S\,p'_1\,K\,p_1 =$ product of scalar contents of (p, q, r, s), (p_1, q_1, r_1, s_1).

47. We have given sufficient illustrations of the value of alternate processes. The symmetric processes are capable of similar development although we have scarcely touched upon them.

A New Form of Galvanometer. By J. Henry Lendi.

The galvanometer which I am about to describe is a result of the difficulties experienced in attempting to make use of several very sensitive galvanometers in the physical laboratory of the Rose Polytechnic Institute. These difficulties are due to local changes in the earth's magnetic field, arising from moving locomotives, electric motors and street cars in the neighborhood of the laboratory. It will be seen that the existing conditions are anything but favorable to the use of a very sensitive galvanometer depending on the earth's field for the directive force.

In the past year or two several attempts have been made to overcome this difficulty by making a galvanometer of the D'Arsonval type; that is, one in which the directive force is independent of the earth's field. This galvanometer differed only from the ordinary D'Arsonval instrument in that the field was excited by an auxiliary battery instead of a permanent magnet. By this means we were able to secure a very intense controlling field, and thereby, thought we should be able to make a galvanometer more sensitive than the ordinary form of D'Arsonval, and at the same time, make use of it in places where there was a liability to local changes in the earth's field.

But in this we were disappointed, for the reason that it was found impossible to make a deflecting coil free from magnetic impurities in both the insulation of the wire and the wire itself.

This magnetic property of the deflecting coil, it is easily seen, introduced a moment opposite to that which tended to produce a deflection of the coil, and therefore greatly reduced the sensibility of the instrument.

This last difficulty would be entirely eliminated if the controlling field were uniform within the limits and in the direction of the motion of the deflecting coil.

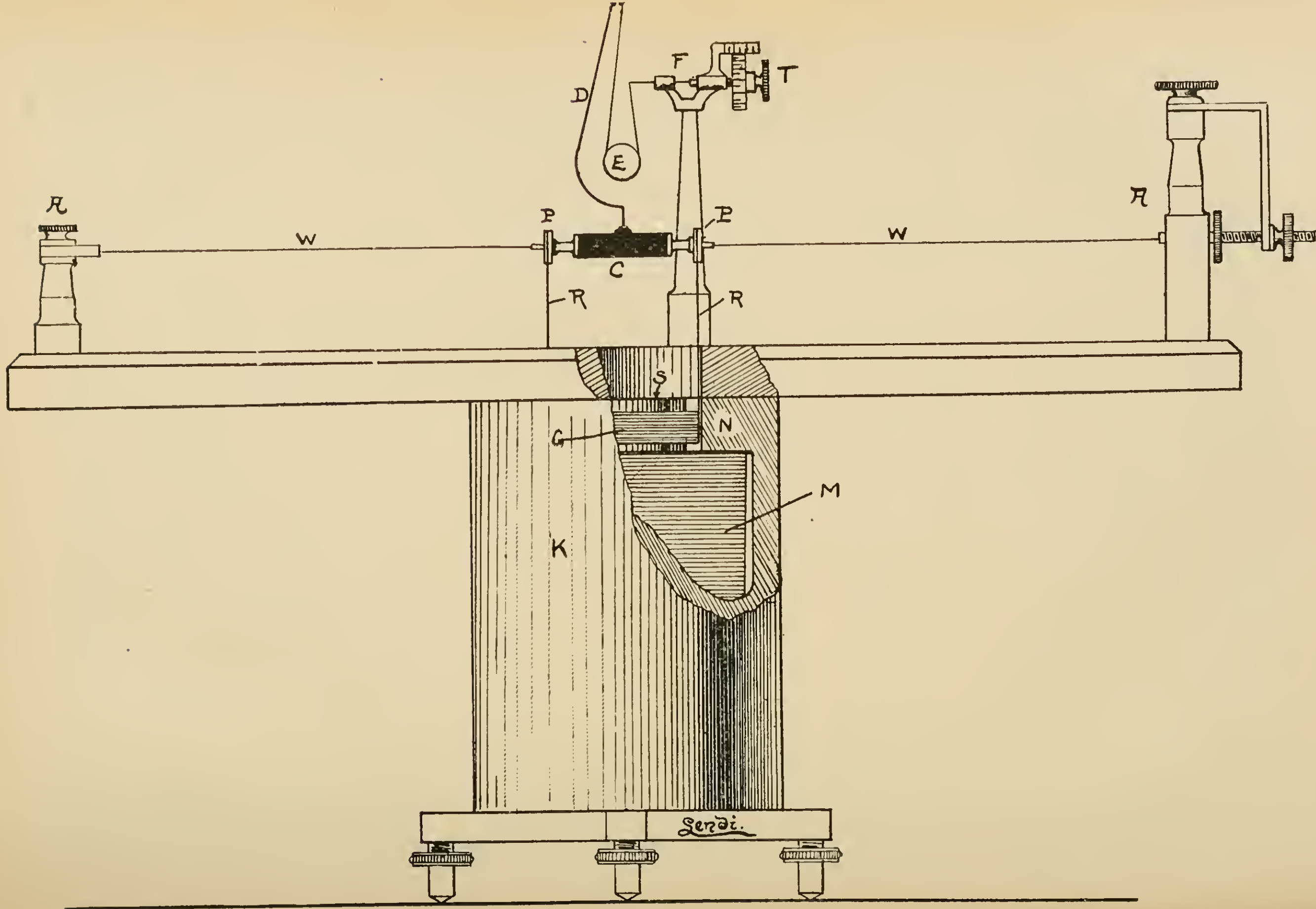
This has, I believe, been accomplished in the instrument I will now describe:

The field magnet is an ironclad electro-magnet of cylindrical form (Fig. 1), the enveloping shell (K) being simply a continuation of the core of the electro-magnet M, the only opening for the magnetic field being an annular slot 1/8" wide, 15/8" outside diameter and of depth 1/2". In this slot the deflecting coil (G) is suspended by means of its two terminals (R, R). This form of field magnet will give us a uniform field in the direction of the slot, provided the two cylinders, forming the slot, have their axes parallel, (not necessarily coinciding).

Still another provision was made to guard against the non-uniformity of the field by multiplying the motion between the deflecting coil and the mirror so that a very small displacement of the coil, and consequently insensible change of field in which it hangs, would produce a readable deflection of the mirror.

This multiplication is accomplished by the peculiar suspending mechanism.

Between the two pillars (A, A) there are suspended two light brass pulleys (P, P) by means of the piano wires (W, W) (diameter .01"). These and the wires are insulated from each other by the piece (C), the faces of the pulleys are directly over the field-gap, and wrapped around them are the two terminals (R, R) of the deflecting coil (G), so that an electric circuit can be established between the pillars (A, A) by way of the deflecting coil.



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Again, to the insulating piece (C) there is attached an arm (D) which supports one of the fibers of the bifilarly suspended mirror (E), the other fiber being attached to a fixed pillar (F), which has an adjustment to change the distance between the ends of the fibers. To explain the action of this mechanism, suppose the field magnet (M) to be excited, and thereby producing a very intense magnetic field in the field gap, and that a small current be flowing in the deflection coil freely suspended in this field gap. The result will be an upward or downward motion of the deflection coil, according to the relative directions of the currents in the two coils.

This motion will be communicated by means of the terminals to the pulleys (P, P), which will be rotated about their axis, the piano wire, carrying the arm (D) with them.

It will be seen that if the ratio of the radius of the pulleys to the arm (D) be 1-r, then will the upper extremity of (D) describe an arc whose length is r d, where d is the distance that the coil moves up or down.

Again, suppose the horizontal distance between the upper ends of the bifilar suspension to be s, then will the mirror (E), which, of course, hangs in the plane of the two fibers, make the angle $\mathrm{Tan}^{-1}\, rd \div s$ with its initial position. And therefore for a given value of rd, the deflection of the mirror will approach a maximum as s decreases.

We are thus able to increase the sensibility of the instrument in a very convenient manner, and what is more, we can change it a given amount at will by simply changing the distance s by means of the gradnated screw (T).

The instrument has been completed but a short time, and therefore we have not been able to give it a fair test, but the experiments that have been made are sufficient to indicate that, with a few changes in the mechanical details, our object has been attained.

Note on Some Experiments to Determine the Ratio Between the Elastic Limit in Tension and in Flexure for Soft Steel. By W. K. Hatt.

The fact that the material at the top and bottom of a beam of ductile material will show an elastic limit in flexure higher than its elastic limit in tension has been noted by experimenters, by Baoshinger and M. Considere, for instance. For steel bars the elastic limit in flexure was $\frac{1}{3}$ to $\frac{3}{4}$ larger than in tension, and the increase is a function of the shape of cross-section and ductility of material. The