

HARMONIC AND "BASIC" LINES AND TENDENCIES.

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From the third law of motion it follows, as a necessary consequence, that cosmical and molecular bodies act and react in accordance with laws of perfect fluidity and of perfect elasticity. Hence, by introducing formulas of hydrodynamic and of undulatory motion, results can often be speedily reached which would, otherwise, require the use of long and difficult analytical processes.

Challis, in the *Philosophical Magazine*, has discussed a great variety of gravitating, electrical and thermal phenomena, from hydrodynamic considerations. Norton, in the *American Journal of Science*, has applied the principles of pneumatics to similar interpretations. The whole theory of thermodynamics rests mainly upon simple laws of motion, which may be readily deduced, as corollaries, from the fundamental propositions of "Newton's Principia."

In the *Monatsbericht* of the Berlin Academy for September and October, 1878, M. Paalzow describes a method of determining the fundamental lines of the oxygen spectrum with great precision, and publishes the wave-lengths of the five most persistent lines, which he regards as specially characteristic. His measurements are given in millionths of a millimetre, in the following table, together with three other series, which serve, by comparison, to indicate the influence of two co-ordinate laws:

	Paalzow.	Harmonic.	Reciprocal.	Geometrical.
O α	602	602	601.91	599
O β	558.2	558.24	558.27	559
O γ	519	519.24	518.74	520
O δ	481	481.10	480.87	484
O ϵ	453	452.77	452.87	451

In the harmonic series if we divide the first term by each of the successive terms, we get the partial harmonic progression, $\frac{1}{1}$, $\frac{1}{1.0784}$, $\frac{1}{1.1594}$, $\frac{1}{1.2513}$, $\frac{1}{1.3296}$. The harmonic denominators are equivalent to 1 , $1 + 29a$, $1 + 59a$, $1 + 93a$, $1 + 122a$, the first difference ($29a$) being also the final difference ($122a - 93a = 29a$).

The reciprocal series is obtained by multiplying 1.6468 successively by 365.5, 339, 315, 292 and 275. The derivation and significance of the common factor, 1.6468, will be explained below.

The terms in the geometrical series are in geometrical progression.

The arithmetical means between the harmonic and reciprocal values are almost identical with Paalzow's measurements. The greatest difference is less than $\frac{1}{25}$ of one per cent., in Os. The least difference is $\frac{1}{519}$ of one per cent. in O γ . The other differences range between $\frac{1}{100}$ and $\frac{1}{320}$ of one per cent.

In previous communications upon spectral harmonies,* I have shown that the Fraunhofer lines of the solar spectrum represent exponential or geometrical values, while the planetary positions represent linear or arithmetical values, in series which are determined by the relations between density and altitude in elastic atmospheres.

I have also shown, elsewhere:† 1. That the collisions of subsiding particles from opposite diametrical extremities of a condensing spherical nebula, tend to form shells, or rings, of nodal aggregation, at $\frac{2}{3}$ of the radial distance from the centre of the nebula.

2. That centres of linear and spherical oscillation exert an important influence, both upon molar and molecular arrangements.

3. That the nodal resistance of large cosmical bodies tends to form other nodal aggregations, at harmonic intervals, in accordance with the laws of musical rhythm which govern the vibrations of elastic media.

4. That there are reasons for anticipating, in the fundamental oscillations of chemical elements, symmetrical harmonic evidences of the same laws as govern the harmonic nodes of elastic media and the harmonic grouping of planetary systems.

5. That in cosmical or molecular aggregation near the foci of paraboloids, there are three wave systems, with tendencies to nodal collisions and the formation of orbits in which the major axes have successive differences of four times the focal abscissa.

6. That centrifugal velocity varies as the fourth power of tangential velocity in a circular orbit.

The distance of projection against æthereal or other uniform resistance is proportioned to the projectile *vis viva*, or to the square of the projectile velocity. The mean *vis viva* of the spherical undulations

* This Journal, October, 1877, p. 284, etc.

† Proceedings Am. Phil. Soc., volumes xii-xviii.

which are generated by Earth's reaction against Sun's action tends, by the laws which govern the moment of inertia, to form a node at $\cdot 4$ of Sun's distance from Earth, or at $\cdot 6$ of Earth's mean radius-vector.

According to Dr. Fuhg's estimate,* deduced from 6827 measurements of Sun's apparent diameter, Earth's distance from Sun is 214·524 solar radii, and Neptune's distance is 6442·985 solar radii. Having already seen that the Fraunhofer line A, with a wave length of 7612 ten-millionths of a millimetre, is the exponential correlative of the planet Neptune,† we readily find that Earth's mean reaction against Sun's action may be represented by a wave-length of 4215·8. For, $\log. 6442\cdot985 : \log. \cdot 6 \times 214\cdot524 :: 7612 : 4215\cdot8$.

If we regard this reactionary value as a fundamental wave-length for terrestrial chemical elements, we may also (by laws 5 and 6) regard $(\frac{1}{4})^4$ of 4215·8 = 16·468 as a fundamental increment for such harmonic undulations as may be excited in an elastic medium by inertial resistance.

We have seen in the foregoing comparative table the influence of this fundamental increment upon the oxygen lines. Multiples of the same increment also appear in the differences between the wave-lengths of other elementary spectra and in Lockyer's "basic lines." Take, for example, Gibbs' groupings of corresponding lines,‡ in Kirchhoff's and Huggins' measurements of the spectrum of arsenic :

Kirchhoff.	Huggins.	Normal.
617·54	617·67	617·54
611·69	611·67	611·69
578·95	578·73	578·75
533·55	533·41	533·55

In the normal column, the shortest wave-length, $533\cdot55 = 2^2 \times 3^4 \times 1\cdot6468$; $617\cdot54 - 533\cdot55 = 51 \times 1\cdot6468$; $611\cdot69 - 578\cdot75 = 20 \times 1\cdot6468$; the second set is harmonically connected with the first, for $617\cdot54 \div 611\cdot69 = 1 + \cdot 009575$, and $617\cdot54 \div 578\cdot75 = 1 + 7 \times \cdot 009575$; the only difference between Kirchhoff's and the normal lines is less than $\frac{1}{28}$ of one per cent. ; the normal difference is precisely equivalent to Kirchhoff's in the first set, and to Huggins' in the second; the sum of the extreme lines is the same in each column ($617\cdot54 + 533\cdot55 = 617\cdot67 + 533\cdot41$).

* Astron. Nachr., 2040.

† This Journal, *loc. cit.*

‡ American Journal of Science, [2], xlvii, 211.

The group of corresponding lines in the spectrum of zinc* exhibits a similar accordance :

Kirchhoff.	Huggins.	Normal.
636·99	637·37	636·99
610·64	610·89	610·64
589·90	589·90	589·55
472·25	471·98	472·31

In the normal column, $636·99 - 610·64 = 2^4 \times 1·6468$; $610·64 - 472·31 = 84 \times 1·6468$; $636·99 - 472·31 = 10^2 \times 1·6468$; $589·55 = 358 \times 1·6468$. As in the foregoing instance, the sums of the extreme lines are nearly equal in all the columns.

Kirchhoff's copper lines † show a more complicated arrangement :

Kirchhoff.	Normal.
578·67	578·67
529·30	529·27
522·24	522·21
465·64	465·75

In the normal column, $578·67 - 529·27 = 30 \times 1·6468 = a$; $529·27 - 522·21 = \frac{a}{7} = b$; $522·21 - 465·75 = a + b$.

Lockyer has published eight "basic lines," which he regards as especially important, ‡ and which furnish farther illustrations of these various harmonies, some of which I foretold ten years ago. || His lines are given in the following table, together with corresponding theoretical lines, which consist entirely of symmetrical multiples of the fundamental increment :

	Theoretical.	Lockyer's Lines.
$(4^4 + 8^2 + 3^2)$	$\times 16·468 = 5418·0$	5416
$(4^4 + 8^2)$	$\times 16·468 = 5269·8$	5269
		5268
$(4^4 + 7^2 + 3^2 + 2^2)$	$\times 16·468 = 5236·8$	5235
$(4^4 + 7^2 + 3^2)$	$\times 16·468 = 5170·9$	$b^3 b^4$
$(4^4 + 7^2)$	$\times 16·468 = 5022·7$	5017
4^4	$\times 16·468 = 4215·8$	4215

My investigations have been entirely independent of Lockyer's, and

* *Ib.*, p. 212.

† *Ib.*, p. 207.

‡ Proc. Roy. Soc., January, 1879.

|| Proc. Amer. Phil. Soc., x., 103; xii., 392 sqq.; xiii., 245; xvi., 507

I was not aware until I learned by the announcement of M. Dumas, in the *Comptes Rendus*, that the distinguished English spectroscopist had obtained any results which would confirm my anticipations. There has been, therefore, no possible opportunity for shaping my theory so as to accord with the facts. I simply showed, upon mathematical grounds, what *must be* the tendencies resulting from the mutual action and reaction of well-known forces. None of the evidences, which I have here adduced, were either known or suspected to exist when I published my papers. These accordances, therefore, have a double value, for they furnish the physical proof, which is most satisfactory, of *a priori* conclusions, and they show that Lockyer's theories, in addition to the evidence which convinced his own mind, have the corroborating support of principles which are operative wherever a ray of light can go and wherever a physical action can awake an equal and opposite reaction.

In comparing the two sets of wave-lengths in the foregoing table, we see that, while there is the general accordance which gives the most satisfactory indication of natural law, there is sufficient deviation from precise coincidence to show the desirableness of further investigation, in order to secure the greatest possible accuracy of measurements, and to eliminate the effects of disturbing influences. In two instances theory gives only a single line (5269·8 and 5170·9) to represent two lines or a doubled line in Lockyer's system (5269, 5268, b_3 , b_4). I can think of no more probable reason for such doubling than a modification of the other activities by centripetal collisions, in accordance with the first of the foregoing principles. The central line of the five theoretical *incremental* lines (5236·8) represents $\frac{2}{3}$ of the interval between the theoretical representatives of the doubled lines (5170·9 and 5269·8).

Lockyer does not give any estimate of the wave-lengths of b_3 and b_4 . Gibbs gives 5177 as the wave-length of the b line. All the theoretical incremental multipliers are integral squares representing thermodynamic increments of *vis viva*, or of inertial moment, which correspond both to increments of temperature and to distance of projection against uniform resistance. The difference between the initial incremental coefficients in the two sets of symmetrical lines ($8^2 - 7^2$) is 15. The greatest square in 15 is 3^2 , which is the first supplementary increment of the coefficient in each set; the greatest residual square in 15

— 3^2 is 2^2 , which is the second supplementary increment in the first set.

The greatest actual difference between the theoretical and Lockyer's measured values ($5022\cdot7 - 5017 = 5\cdot7$) is only $\frac{1}{40000000}$ of an inch.

This is, however, nearly 35 per cent. of the fundamental increment, a deviation which would materially affect the credibility of the theory if only the simple increment in this single instance were in question. But the deviation is only $\frac{5}{7}$ of one per cent. of the multiple increment, which the law of symmetry requires, ($7^2 \times 16\cdot468$), and less than one-eighth of one per cent. of the total wave-length. If we reduce each of the theoretical values about $\frac{1}{35}$ of one per cent., by dividing by $1\cdot00028$, the general closeness of accordance will be more readily seen.

Reduced Theoretical.	Measured.
5416	5416
5268	5269
5268	5268
5235	5235
5021	5017
4215	4215

In my paper upon the "Music of the Spheres,"* I showed that the positions of the various primary planets are more accurately represented by these laws of harmonic oscillation than by either of the merely empirical series that have been devised, and even more accurately than by Peirce's phyllotactic series, which comes next to my own in order of precision, and which may also be explained by harmonic tendencies that were pointed out by Laplace in his "*Mécanique Céleste*." I have since published various confirmations of astronomical predictions,† which it may be well to collect and repeat in this connection, but in order to correct some erroneous impressions in regard to the character of the anticipations and in order to show the remarkable generality of the influences which have justified forecasts in such different fields of investigation, I give below the three known terms on which the prediction was founded, together with eleven subsequent verifications, and one missing term representing a necessary tendency which is mathematically demonstrable and which, I am confident, will be hereafter veri-

* This Journal, September, 1877.

† *Ib.*, Oct., Nov., 1878; March, 1879.

fied. The numerator a represents $\frac{2}{3}$ of Jupiter's semi-axis major, in accordance with the first and fourth of the foregoing principles.

Prediction.		Verification.	
$\frac{a}{1} = 3.469$		Asteroid 87	3.482
$\frac{a}{5} = .694$		Venus, mean perihelion	.698
$\frac{a}{9} = .385$		Mercury, mean	.387
$\frac{a}{13} = .267$		De la Rue, Stewart and Loewy	.267
$\frac{a}{17} = .204$		Kirkwood	.209
$\frac{a}{19} = .183$		Watson, II.	.180
$\frac{a}{21} = .165$		" I.	.164
$\frac{a}{25} = .139$	
$\frac{a}{29} = .120$		Von Oppolzer	.123
$\frac{a}{33} = .105$		Helios	.106
$\frac{a}{177} = .0196$		Themis	.0196
$\frac{a}{321} = .0108$		Eunomia	.0108
$\frac{a}{465} = .0074$		Phaos	.0075
$\frac{a}{609} = .0057$		Lychnis	.0056
$\frac{a}{753} = .0047$		Sun's surface	.0047

It has been urged, as an objection to this series, that the existence of any intra-mercurial planets is still a mooted question. The objection may be answered as follows:

1. My investigations have been limited to the demonstration of *tendencies*. After I had found that the influences of harmonic oscillation were traceable from *Alpha Centauri* to the solar system, and also in the position of all the known planets and satellites within our system, it was evident that those influences do not stop at the orbit of Mercury, but that they must extend to the Sun. There was, therefore, little risk in predicting that evidences of such intra-mercurial activity would be found. This prediction was completely verified when De la Rue, Stewart and Loewy announced the discovery of their sun-spot period, with its alternating northern and southern maxima.

2. Tendencies of one kind are often modified or completely over-ridden by tendencies of another kind. In view of the many perturbations to which any intra-mercurial bodies must be subject, it is

reasonable to believe that asteroidal aggregations may be alternately formed and broken up, in the neighborhood of harmonic nodes, and even to look for future conclusive evidence of such shifting arrangements of "cosmical dust." No one who knows the ability and prudent cautiousness of Professor Watson can well doubt that the two unknown bodies which he saw during the last total solar eclipse, were either planetary or cometary.

3. The necessity that rotary oscillation should obey harmonic cyclical laws is just as great as the necessity that the oscillations of planetary revolution should be harmonic. Therefore, the discovery that the three known systems of rotation, in the belt of light planets, in the belt of dense planets, and in the sun itself, are represented by the harmonic series which is established by the combined action and reaction of Sun, Earth and Jupiter, furnished three additional and indubitable verifications of prediction (Helios, Themis, Eunomia).

4. The discovery that the node of Herschel's theoretical "subsidence" (Lychnis), is harmonically intermediate between Sun's surface and "Phaos," and that this ternary system also completes a series of co-ordinate harmonic groupings which begin in the region of the fixed stars and end in the sun, furnished three additional and indubitable verifications of predictions.

5. With regard to the four remaining verifications, we may admit that they are less complete than the others; but the simple names of Kirkwood, Mouchez, Gaillot and Von Oppolzer are sufficient guarantees of the fact that planetoid sun-spots and planetary bodies have been seen in positions all of which can be satisfactorily accounted for by the hypothesis of the four harmonic orbits which these astronomers have computed. Whether the spots and bodies were transient or permanent is a matter of no consequence; the fact remains that the indications exist, and the discovery of those indications furnished four additional verifications of prediction. That there are many others in the fields of astronomy, optics, electricity, thermodynamics, chemistry and general physics, I am sure. That many of them will be discovered hereafter I most confidently and unhesitatingly believe.

invention of Mr. Timius Olsen, and most of them are fully described in the accompanying copies of recent patents granted to him.

In the patent of March 25th, 1879, No. 213,525, is described some improvements on their 40,000-lbs. vertical machine. A loose cross-head is suspended by long links from the upper tools, and reaches below the lower tools, for the purpose of enabling compression and transverse tests to be made without any change in the machine, and, at the same time, serving as a guide for the lower tools. This is a decided improvement, adding to the convenience and usefulness, without much increasing the cost.

An arrangement is also shown for lifting the jack after a specimen has broken, or to adjust for length. We do not approve of this, for the reasons that, in our opinion, the chain-wheels would cause one screw to lead the other; that it would be a slow process, running the screws down until the pawls engaged with the rods on the jack; that the pawls would prove troublesome and not act well. This arrangement is also intended to hold down firmly the cross-head of the plunger when a specimen is under stress, so as to prevent this stress from being relieved by any leakage from the jack or connections. For this purpose the device is useful.

The general design of this machine is good. It is compact, while, at the same time, the parts are accessible. The jack is worked by a single hand-pump. The beam and poise are in a convenient position, close to the pump and to the tools. One man can make careful tests, as everything is within easy reach. We can commend this as being a useful and handy size and form of testing machine. It is intended for testing specimens cut to a certain size so as not to exceed its capacity.

Patent No. 212,107, granted to Mr. Olsen October 25th, 1878, describes a much larger vertical machine, for testing materials in the actual shapes and sizes used in construction. When practicable, this is a better method, and gives more reliable results. We thoroughly examined a machine of this form of 100,000 lbs. capacity, built for the Pennsylvania Railroad Co.'s shops at Altoona. The arrangement of the platform, levers and jack is remarkably compact, and this, together with the great capability of adjustment of the cross-head carrying the lower tools, enables tests to be made of articles of unusual length. The jack is inverted and bolted to the bed of the machine underneath the platform. This economizes room, but at the expense of convenience for repairs. Instead of a single acting plunger, the jack

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has a piston which receives the pressure either on its entire upper surface, for producing the stress, or on its annular under surface, for returning it to position. The pressure is produced by a triple-acting pump worked by belt-power. A rod and hand-lever in front of the platform and immediately below the scale-beam operate the valves, which are so arranged that the flow of the fluid can be shut off without relieving the pressure in the jack or stopping the pump; or the flow can be so directed as to cause the plunger to move in either direction as desired. One man can thus conveniently control the pressure and move the poises without changing position. The location of the specimen is, however, inconveniently high.

A good feature, described in this patent, is that of the adjustable rods, which can be screwed down hard against the cross-head of the plunger, preventing the stress from being relieved by any leakage when the pumps are shut off from the jack for a considerable length of time, as is often desirable; but this does not provide for the relieving of the stress on the specimen occasioned by its own stretching.

Olsen's patent of April 8th, 1879, No. 213,998, describes another form of vertical machine for still heavier purposes. In this case the jack is placed at the top, resting on the weighing mechanism. Its plunger is connected by rods with a cross-head which acts on one end of the piece being tested, the other end of the piece being held by the bed of the machine. The position and arrangement of the cross-heads and tools are very convenient, and long pieces can be readily handled. We regard this as an important feature. The jack, instead of being supported on one main lever, with its fulcrum in the line of strain, in which case it would be in a condition of unstable equilibrium, is made to rest on two levers of different lengths but of the same count, and so placed that the line of strain passes between their fulcrums at distances from each relatively proportional to their lengths. This gives a good broad base to firmly support the jack, and, together with the arrangement of links between the main and intermediate levers, makes an ingenious and efficient construction. Messrs. Riehlé Bros. have never built machines on this plan, but we think it has advantages, and promises to be superior in many respects to the other forms. A drawing of a 150,000-lbs. machine of this style is appended.

Patent of February 25th, 1879, No. 212,734, describes a horizontal machine of 300,000 lbs. capacity, designed especially for testing chain, and built for, and in daily use by, Messrs. Bradlee & Co., of this city.

In this machine the stress is produced by a jack worked by triple-pump driven by belt-power. The jack is at one end of the apparatus and the weighing mechanism and pumps at the other. Heavy timbers are placed between, enabling any length to be obtained, Messrs. Bradlee's machine being about 130 feet over all.

In a horizontal machine of this length and power, special arrangements are necessary to allow for the recoil, both of the jack and of the main weighing levers, which occurs when a heavy chain or other article breaks under strain. This has been well provided for by the devices described in the patent.

Your committee visited Bradlee's chain works, saw the machine in practical use, and tested in it a chain having links made of $3\frac{1}{4}$ -inch round iron, on which was put a strain of 300,000 lbs., the full capacity of the machine. The result was very satisfactory, although, when at its maximum, the machine began to show signs of effort, and could hardly be recommended for continuous work of so great severity.

The triple pump, used to work the jacks of this and other machines, consists of three single-acting plungers, which receive motion, through walking beams, from three cranks at angles of 120 degrees with each other, the objects being to give a steady supply of fluid to the jack and to avoid blows. The stroke of these plungers is made adjustable, so as to vary the power and speed to suit the nature of the test being made. This is accomplished by changing the position of the fulcrums of the walking-beams, as follows: A sliding frame, moved by a screw and hand-wheel, carries a shaft on which are fitted three boxes, each of which has a flat top and bottom fitting between the two halves of the walking-beam, after the manner of the locomotive slide-link. One end of each walking-beam is journaled to a crank, and the other end is connected by links to a plunger. It is evident that when the shaft, which is carried by the sliding frame, is central between the two ends of the beam, the stroke of the plunger will be equal to the entire throw of the crank, or to double its radius. If the frame be moved toward the pump end, this stroke will be diminished, and *vice versa*. As this adjustment can be made without stopping anything, it forms a very convenient and effective arrangement. There is considerable slide of the walking-beams on the fulcrum boxes, owing to the fact that one end of the beams receives a rotary motion from the cranks. This produces an amount of friction that is very noticeable under heavy strains, and which could be suitably provided for by a proper amount of surface.

Olsen's patents of March 25th, 1879, No. 213,525 and No. 213,586, describe tools for holding the ends of specimens while being tested for tensile strength. We did not see either of these in practical operation, but it is claimed that they are a decided improvement on the old methods. We rather question the advisability of making the tool to act as an universal joint, for in case the axis of the test piece were out of line with the axis of stress, this arrangement would be apt to do more harm than good. What is wanted is a device that will infallibly grip each end of the piece so that its centre-line corresponds with the centre-line of pull. The feature of allowing the wedges to accommodate themselves to any irregularities is proper, but the tool should also fill the conditions named above.

The various forms and sizes of testing machines designed by Mr. Olsen and manufactured by Messrs. Richlé Bros. really constitute a new industry in this country, and particularly in this city. Messrs. Richlé Bros. have undoubtedly increased the interest in, and desire for, more extended data as to the qualities of materials. They have placed within the reach of manufacturers good, practical and reliable means of ascertaining these qualities, and it is to be hoped that their efforts will tend to aid the continual improvement of our products, and thus be of great service in the advancement of our mechanical industries.

Although we may criticise some of the details of their machines, and may, in some cases, see room for improvement in workmanship, yet we heartily commend their aims, and think they deserve great credit for what they have already done and are now doing.

Respectfully submitted.

WM. H. THORNE.

L. R. FAUGHT.

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WM. D. MARKS.

Improved Vulcanized Rubber.—C. Schwanitz, Jr., of Berlin, uses glycerin in the preparation of vulcanized rubber, in order to secure it from injury by fats and oils. He also passes the finished mass between warmed rolls, in a glycerin bath, in which it is exposed to steam, under a pressure of two or more atmospheres.—*Dingler's Journal*. C.