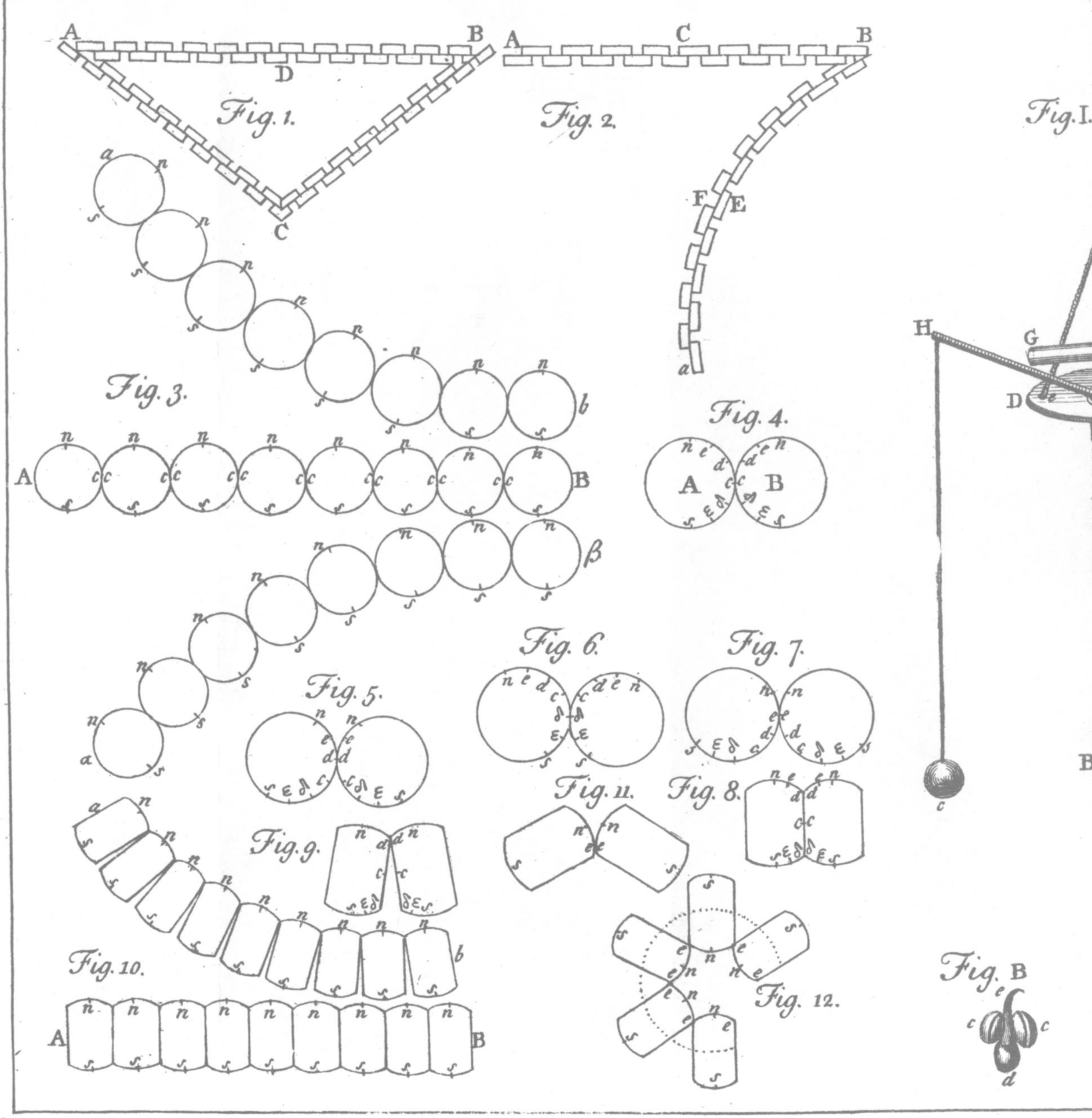
Philosoph. Transact. N.° 454. TAB. I.



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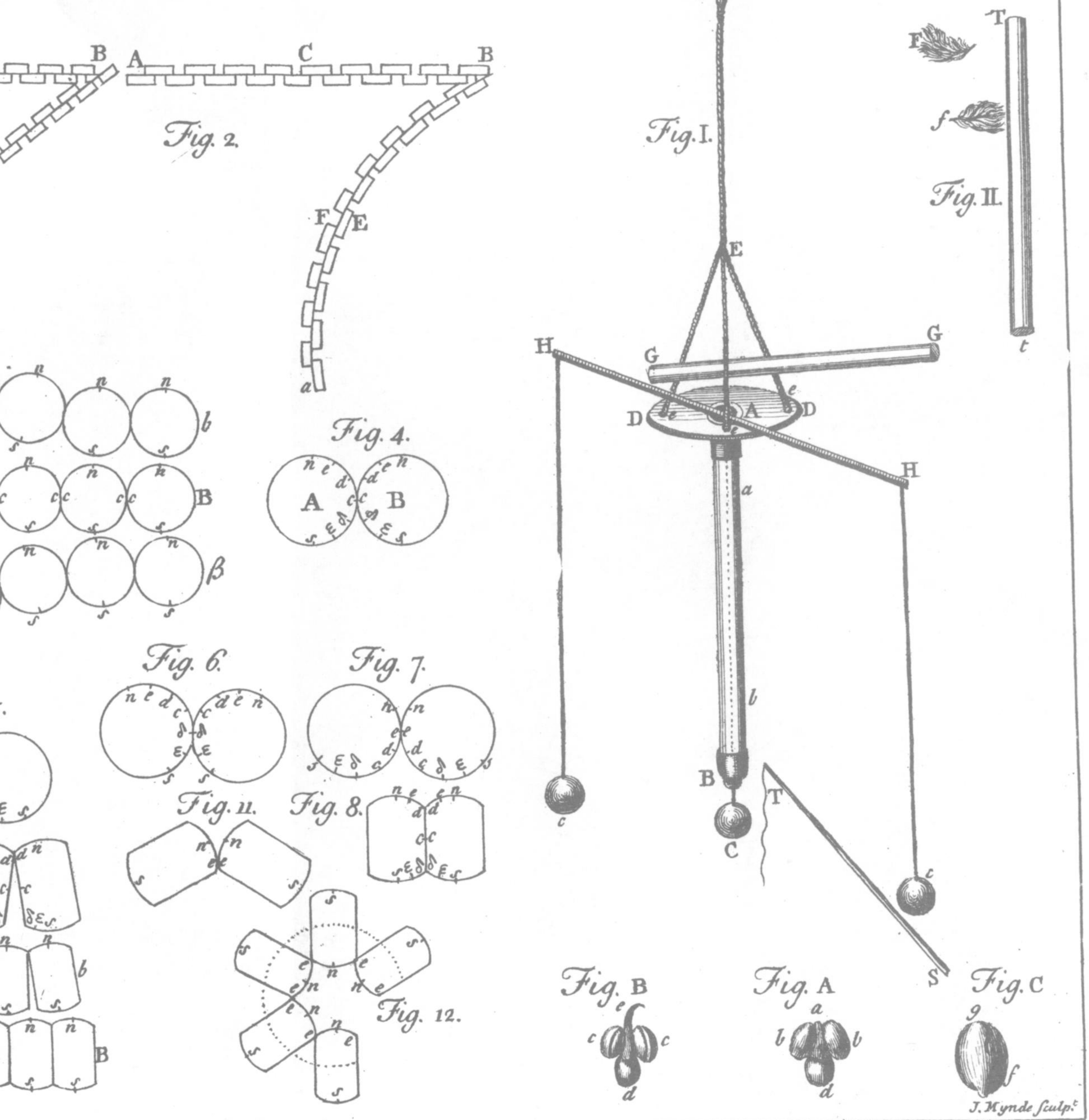

Fig. 2.
Fig. I.
Fig. II.
Fig. 4.
Fig. 6.
Fig. 7.
Fig. 11.
Fig. 8.
Fig. 12.
Fig. B
Fig. A
Fig. C
J. Mynde sculp.t

Latitude. North. °	′	Longitude West. °	′	Sun's Altitude.	Variation. West. °	′
28	55	39	28	27	5	23
29	8	40		26	7	12
31	10	44	46	30	8	6
31	7	46	45	22	4	46
30	42	49		38	4	40
30	29	49	48	22	4	
30	31	52	10	25	4	49
30	18	53		25	4	45
30	23	55		25	4	22
30	58	57	30	22	4	52
37	9	68		38	4	50

VI. *Some* Thoughts *and* Conjectures *concerning the* Cause *of* Elasticity, *by* J. T. Desaguliers, *LL. D.* F. R. S.

ATtraction and Repulsion seem to be settled by the Great CREATOR as first Principles in Nature; that is, as the first of second Causes; so that we are not solicitous about their Causes, and think it enough to deduce other Things from them. If Elasticity was admitted as a first Cause, (as it is by some) it is thought we should admit of too many principal Causes in Nature, which is contrary to the Rules of good Philosophy. Philosophers therefore have endeavour'd to deduce Elasticity from Attraction, or from Repulsion, or from both. It is observ'd, that the same Particles that repel each other strongly, will attract other Particles very strongly; as appears by many Chemical Dissolutions, especially by the alternate Dissolution and Precipitation of Metals in acid *Menstruums*. The Reverend and Learned Dr. *Hales* has proved this many Ways, in his *Vegetable Statics* and *Hæmastatics*. The Elasticity of Air seems to consist wholly in the repulsive Power of its Particles, which do not touch one another while the Air is in its elastic State; and if those Particles be brought nearer and nearer together, the Effect of their repulsive Force will increase, the Air's Elasticity being always proportionable to its Density by Compression, which Property will be preserv'd, though compress'd Air be kept a Year or two; notwithstanding Mr. *Hauksbee* in his *Physico-mechanical Experiments* says, that Air will lose part of its Spring by being very much compress'd. But the Air with which he try'd it, must have been fill'd with moist Vapours; and it is well known, that the Steam of Liquors will lose its Elasticity, especially where its Heat decays. I have kept several Wind-Guns, strongly charg'd, for half a Year together, in which the Air had lost none of its Elasticity: Others have found the Air as strong after a Year; and I have been told by a Person of Credit, that a Wind-Gun having been laid by and forgotten for seven Years, when it was found, discharg'd its Air as many times, and with as much Force, as it used to do. Now, though Air, compress'd by any external Force, does always increase in Elasticity, as it diminishes in Bulk; yet it may, by Fermentation, diminish its Bulk very much, without gaining any more Elasticity: For if another Fluid, whose Parts repel one another, but attract the Parts of Air, be

mix'd

mix'd with Air, the Repulſion of any two Particles of Air will be diminiſh'd, in proportion as a Particle of the other Fluid, inſinuating itſelf between them, attracts them towards itſelf on either Side. The ſame thing will happen to the other Fluid, in reſpect of the Particles of Air, which mixing with its Particles, do in the ſame manner deſtroy their Repulſion. Thus, if we allow an Attraction ſtrong enough between the Parts of two elaſtic Fluids, it is poſſible, that by Fermentation a Solid may be made out of two elaſtic Fluids, which would have ſtill continued fluid without ſuch a Mixture. We are taught by Chemiſtry, to mix Fluids together, which immediately coaleſce into a Solid. When Brimſtone Matches are burning, the *Effluvia* of the Sulphur repel each other to great Diſtances, as may be known by the ſulphureous Smell upon ſuch an Occaſion. Now, though theſe Particles repel each other, they attract the Air very ſtrongly, as appears by the following Experiment:

Take a tall Glaſs Receiver cloſ'd at Top, holding about four Quarts of Air, and having put its open End over a Bundle of Brimſtone Matches on Fire, ſtanding up in the Middle of a large Diſh with Water in it, (to keep the Air from coming in at the Bottom of the ſaid Receiver) you will obſerve, that not only as ſoon as the Matches are burnt out, but a good while before, the Air, inſtead of being expanded by the Flame of the Brimſtone, will retire into leſs Compaſs, the Water beginning to riſe from the Diſh up into the Receiver, and continuing ſo to do till ſome time after the Matches are burnt out; ſo that there will be in the Receiver only three Quarts of Air, inſtead of four (more or leſs, in proportion to the Quantity of Brimſtone burnt): And this plainly happens by ſome of the *Effluvia*, or little Parts of the Sulphur, attracting ſome of the Particles of the Air, ſo as to make an unelaſtic Compound, that precipitates into the Water. If the Elaſticity of the Air is quite loſt when the Repulſion of its Particles is taken off, or ſufficiently counteracted, it muſt follow, that its Elaſticity depends upon Repulſion: And that this is often the Caſe, appears by a great Number of Dr. *Hales*'s Experiments, of which I will mention but a few. The Doctor took a Cubic Inch of Mutton-Bone, and having put it into his Gun-Barrel Retort, he diſtill'd out of it two or three hundred Cubic Inches of Air into a large glaſs Bottle, the Weight of which Air, together with the Aſhes of the Bone left, weighed as much as the whole Quantity of Bone did at firſt. Now the Air had been confin'd in that Bone, together with many ſulphureous Particles, in ſuch manner, that the mutual Attraction of the Sulphur and the Air had alternately deſtroy'd each other's repulſive Force, and brought thoſe Subſtances into a little Compaſs; but the Fire in the Diſtillation ſeparated them from each other, ſo as to reſtore them, in a great meaſure, to their uſual Elaſticity. This appear'd by bringing a Candle near the Mouth of the Bottle that held this reviv'd Air; for every time the Candle was brought near, the Air took Fire, and flaſh'd out of the Bottle with a ſulphureous Smell. The Air may be conſolidated in many hard Bodies, ſo as to be there quite void of Elaſticity, and there do the Office of a Cement, till by the Action of Fire, or ſome particular Fermentations, it is again reſtor'd to its perfectly elaſtic State.

This

This is the Meaning of the Doctor's Words, when he ſays, that ſome Bodies *abſorb*, and others *generate* Air; and the ſame Bodies do ſometimes abſorb, and at other times generate Air. He found more or leſs Air in almoſt every ſolid Subſtance that he try'd; but, what was moſt remarkable, he found that the *Calculus humanus* (or Stone taken out of a Man's Bladder) was made up of above half its Weight of Air.

Some have endeavour'd to ſolve Elaſticity by Attraction only; as for Example: If the String *AB* (Tab. I. Fig. 1.) be conſider'd as made up of Particles lying over one another in the manner repreſented at *ADB*; it is plain, that if the Point *D* be forcibly brought to *C*, the Parts will be pull'd from each other; and when the Force, that ſtretch'd the String, ceaſes to act, the Attraction of Coheſion (which was hinder'd before) will take place, and bring back the String to its former Length and Situation after ſeveral Vibrations. Now, though this ſeems to agree pretty well with the *Phænomena* of a String in Motion, it will by no means ſolve the Elaſticity of a Spring faſten'd at one End, and bent either way at the other, like a Knife or Sword-blade, as in Fig. 2. For if ſuch a Spring be bent from *A* to *a*, the Particles on the Side *C*, which now becomes convex, will be farther aſunder at *F*, while the Particles at *D*, carried to the concave Part *E*, will come cloſer together: So that the Attraction, inſtead of making the Spring reſtore itſelf, will keep it in the Situation in which it is, as it happens in Bodies that have no Elaſticity, where perhaps only Attraction obtains. Thus a Plate of Lead, a Plate of Copper, and a Plate of ſoft Iron, ſtands bent.

But

But the moſt probable way of ſolving the Elaſticity of Springs, is to conſider both a repulſive and an attractive Property in the Particles, after the manner of the black Sand, which is attracted by the Loadſtone, and has been ſhewn by the learned and ingenious Profeſſor *Petrus van Muſchenbrook*, to be nothing elſe but a great Number of little Loadſtones.

Fig. 3. Let us ſuppoſe a Row of round Particles touching one another only in the Points *c* in a Line from *A* to *B*. It is plain, from what Philoſophers have ſhewn, concerning the Attraction of Coheſion, that upon the leaſt Shake, or Alteration of the Poſition of a ſtrait Line, theſe Particles will run together, and form a Sphere, in which the Globules will have more Points of Contact. But if theſe Particles have Poles like Magnets in the oppoſite Places mark'd *n*, *s*, ſo that all the Poles *n*, *n*, *n*, &c. repel one another; and all the Poles *s*, *s*, *s*, &c. do likewiſe repel one another, the Line *AB* will continue ſtrait; for if by any Force the ſaid Line *BA* be put into another Poſition, as into the Curve *ba*, then the Poles *nn*, &c. being brought nearer together, (while the Poles *s*, *s*, &c. are farther aſunder) will repel one another more ſtrongly, and thereby hinder the Globules from running together towards the concave Part; and the Spring, left to itſelf, (all this while ſuppoſing one End, as *b*, *B*, or β, fix'd) will reſtore itſelf, throwing its End *a* back to *A*, and ſo on to α, by the firſt Law: Then being in the Poſition $\alpha\,\beta$, the Poles *s*, *s*, &c. are brought nearer together, whoſe Repulſion, thus increas'd, throws back α to *A*, and ſo on forward, the Line of Particles performing ſeveral Vibrations round *B*.

May

May not a Spring of Steel, or other Springs, consist of several Series of such Particles, whose Polarity and Attraction acting at the same time, will shew why such Bodies, when they have been bent, vibrate, and restore themselves?

If we take a Plate of Steel, and make it so hot till it looks white, and then immediately quench it, we thereby fix the Metal in a State very near Fluidity, so that the Particles which the Fire had almost brought to Roundness, have but a very small Contact; as appears by the Fragility of the Steel thus harden'd, which breaks like Glass, and has a short Grain. Steel, thus harden'd, is highly elastic; for what Workmen call *hard*, is the most *elastic*: as appears by the Congress of high-harden'd Steel Balls, which return, in their Rebound, the nearest to the Place we let them fall from; and, next to Glass, have the quickest Elasticity of any thing we know.

That we may not be thought to have given an imperfect Account of the Elasticity of a Steel Spring, because such an one as we have describ'd wants Toughness, and will immediately fly when bent to any Degree; we must beg Leave to consider farther the Properties of the round Particles, or little Spheres, of Steel, in which we have suppos'd a Polarity.

Let us suppose *AB* (Fig. 4.) to be two little Spheres or component Particles of Steel, in which, at first, we will suppose no Polarity, but only an Attraction of Cohesion. Then, whether the Particles have their Contact at *c*, *d*, *e*, *n*, or at *δ*, *ε*, *s*, their Cohesion will be the same; and the least Force imaginable will change their Contact from one of those Points to another; because in the rolling of these little Spheres, they

they do not come into more or leſs Contact in one Situation than another. But if we ſuppoſe the Point *n* in each Spherule to be a Pole with a Force to repel all the other Points *n* in any other Spherule, and likewiſe *s* another Pole, repelling the other Points *s*; the Spherules will cohere beſt, and be at Reſt in that Poſition where the Points *c*, *c*, are in Contact, and *n* and *s* at equal Diſtances on either Side. For if the Spherules be turn'd a little, ſo as to bring the Points *d*, *d*, into Contact, as in Fig. 5. the Poles *n*, *n*, being brought nearer, act againſt each other with more Force than the Points *s*, *s*, which are now farther off, and conſequently drive back the Spherules to the Contact at *c*, *c*, beyond which continuing their Motion, they will go to *δ δ*, Fig. 6. and ſo backwards and forwards, till at laſt they reſt at *c*, *c*, which we may call *the Point of Æquilibrium for Reſt* in a Spring. Now there are, beſides this, two other *Points of Æquilibrium*, beyond which the Spring may break, which are the Points *e*, *e* towards *n*, and *ε*, *ε* towards *s*; ſee Fig. 7. that is, when the Spherules have their Poles *n*, *n* brought very near together, the mutual Repulſion increaſes ſo, that the Attraction at the Contact is not able to hold them, and then they muſt fly aſunder, the Spring breaking. We ſuppoſe the Points *e*, *e*, to be the Points of Contact, beyond which this muſt happen; but that if the Contact be ever ſo little ſhort of it, as between *e* and *d*, the Spherules will return to their Contact at *c*, after ſome Vibrations beyond it, as has been already ſaid. This is the Reaſon why I call *e*, (in one of the Spherules) and its correſpondent Point *ε* on the other Side *ε*, *the Points of Æquilibrium*; for if the Spring be bent

bent towards *a* (Fig. 3.) ſo that the Spherules, like *A* and *B*, (Fig. 7.) touch beyond *e*, the Spring will break: Likewiſe if the Spring be bent the other way, till the Spherules touch beyond ε, then it will break the other way. Now when the Spherules touch at *e*, *e*, or at ε, ε, the Spring is as likely to return to its firſt Poſition as to break; for which Reaſon I have call'd the Points *e* and ε, *Points of Equilibrium*, as alſo having known by Experience, that a Spring left bent to a certain Degree, has, after ſome time, broke of itſelf.

From all this it appears, that Spherical Particles will never make a tough Spring; therefore the Figure of the Particles muſt be alter'd, in order to render it uſeful; and this is what is done in bringing down the Temper of the hard Steel, and *letting down a Spring*, as it is call'd. What Change ought to be made in the Particles, we ſhall firſt ſhew; and then conſider how far that is done by thoſe who make Springs.

If the Parts ſuppos'd Globules, as in Fig. 3. are now flatten'd at *c*, where the Contact is, ſo as to put on the Shape *n e d c* δ ε *s*, (as in Fig. 8.) the Contact will be much increas'd, and reach from *d* to δ, ſo that in bending the Spring there will ſtill remain a great Contact in the Particles, and the Points of Æquilibrium for breaking (*viz.* *e*, *e* above, and ε, ε below) will be remov'd nearer to the Poles *n*, or *s*, than when the Particles are round; the Conſequence of which will be, that the Spring muſt be bent much farther, to be in Danger of breaking, than in the former Suppoſition; as may be ſeen in Fig. 9. where two Particles being open'd about the Point *d* as a

Centre, the attracting Points *c, c*, and *δ δ*, have still some Force to help to bring back the Particles to their whole Contact; because in this Shape of the Particle the attracting Points *c, c, δ, δ* are remov'd but in Proportion to their Distance from the angular Point *d*; whereas if the Particles had been spherical, and the Line *d δ* an Arc of a Circle, the attracting Points *c, c*, and *δ, δ*, would have remov'd from one another farther than in Proportion to twice the Square of the Distance from *d*, (as in Fig. 5.) and so have afforded very little Help for bringing back the Particles to their Contact. A Row of Particles in the Spring thus condition'd, is to be seen in the natural State at *B A*, Fig. 10. and bent at *b a* in the same Figure. Here it is to be observ'd, that if in this Figure of the Particles you would bend the Spring to bring the Particles to touch at their Point of *breaking Æquilibrium*, you must open them so much on the contrary Side, that the Spring will be bent far beyond any Uses intended to be made of it, as appears by Fig. 11. where two Particles are brought to touch at the equilibrating Point *e*; and by Fig. 12. where many Particles being put into that Condition, the Spring is brought round quite into a Circle.

Now the common Practice in making Springs is the most likely to produce this Effect requir'd in the Particles; for the hard Spring, whose Particles were round, or nearly so, is heated anew, and whilst it is cooling gently, the mutual Attraction increases the Contact, so that the Particles grow flatter in those Places where before they had but a small Contact; and lest this Contact should become too great, the Spring's Softening is stopp'd by quenching it in Water,

or

or Oil, or Greafe. Another way of making Springs, is to begin and fhape them in cold unelaftic Steel, and then having heated them to a fmall Degree, for Example, to a Blood red Heat, immediately to cool them in fome proper Liquors. This alfo fettles the Particles in their oblong Figure, through which they muft pafs before they become round, or nearly fo, in a white Heat. That Particles of Steel are fix'd in the Figures which they have at the Inftant of dipping will not appear ftrange, when we confider, that dipping red-hot Steel in cold Liquors, in a particular Pofition, makes it magnetical. If it be ask'd, How we account for making Springs only with hammering, it is eafily anfwer'd, That we can make Iron and Steel magnetical only with hammering; and if we can give and deftroy Poles in the whole Piece, there is no Improbability to think we can give Poles to little Parts; or rather bring into a particular Situation the Poles which they have; for if the Poles that we have confider'd be plac'd quite irregularly, there will be no Elafticity at all. Agreeable to this, Springs may be made of other Metals than Iron or Steel, though not fo perfect, by Hammering; for it will be fufficient for the little Particles to have Poles that attract and repel one another, driven by the Hammering into a regular Order.

N. B. *This, apply'd to the Vibration of a String, will better folve its feveral Cafes than Attraction alone*; and the Elafticity of Glafs is juft the fame as that of a very brittle *Steel-Spring*.