TO PARKER CLEAVELAND[1]

Manuscript Collection, Burndy Library, Norwalk, Connecticut

Albany May 8th 1832

Dear Sir

After a delay which I fear has nearly exhausted your patience I have at length sent off your magnet according to the directions given in your letter of the 8th of Dec.[2] I can get nothing made in Albany in the philosophical line except I stand continually over the workman during the operation or unless, which is most often the case, I do the work intirely myself, and for two months past my time not devoted to my duties in the academy has been so much occupied by an engagement which required my particular attention that I could find no leisure until lately to make the necessary experiments relative to the proper size of the battery. I hope however the article will be received in time for exhibition to your present class[3] and that you and they will not be disappointed in its magnetic power. It was shipped from here on the 4th inst. The following is a particular description of the magnet its construction method of experimenting with it etc.

The horseshoe[4] was formed of a bar of American iron which according to the mechanic who did the filing was unusually hard. It was by no means selected on this account but was taken because it happened to be the only piece of the proper size to be procured in Albany at the time. After bending it into the required form the edges were first rounded with the hammer and afterwards with a file and in order to prevent the slipping off of the wires to be coiled around it a deep groove was filed into each leg about ½

[1] Although we have other correspondence of Henry's on the subject of electromagnets, their construction, and their intensity, this is clearly the most extensive. In writing to Cleaveland, Henry prepared a preliminary draft which he subsequently expanded into the letter below. It is in the Henry Papers at the Smithsonian Archives. A comparison of the retained draft and Henry's outgoing letter reveals some important differences. The draft is written in general terms with less attention to details and few explanatory sketches. It is uncommonly neat in appearance, shows signs of careful preparation, and is noticeably lacking in canceled matter and marginal insertions. In sum, it has all the characteristics of an outgoing letter, but bears the following note: "Draft of Letter to Prof Cleaveland Describing Magnet, May 8th 1832," and is, therefore, without address or postmark. Where significant differences in content occur, the text of the draft is given in footnotes. Stylistic differences and minor changes have been silently passed over.

[2] See above, December 8, 1831.

[3] Unfortunately, the magnet did not arrive until June 1, too late to be exhibited by Cleaveland to his chemistry students. See Cleaveland's letter of June 2, 1832, to Henry, below.

[4] The core of the Cleaveland magnet here described is now in the collections of the Smithsonian Institution's National Museum of History and Technology, Washington, D.C.

an inch from the end. The horseshoe when it came from the hands of the "Finisher" weighed 60 lbs and the armature about 20 lbs: these are almost precisely the same weights of the armature and magnet of Yale College. The winding on of the wires was done with great care under my constant inspection and according to a method which I think much preferable to any before adopted. Instead of covering the wires with cotton or silk thread as in former experiments I gave them several coatings of a varnish made of shellack and mastic and in order to render the insulation still more perfect a thickness of silk was woven as it were between every spire or turn of each wire and the several layers of wires were separated from each other by an intervening thickness of silk and varnish. The operation was as follows: the iron horseshoe was in the first place covered with a coating of varnish and while this was yet soft the whole was wound with strips or ribbons of silk. A coating of varnish was then given to the silk and suffered to become dry before the winding of the wire was commenced. In coiling on the wire one *spire* was passed around the horseshoe with the end of a broad flap of silk between it and the iron. The silk flap was then turned back and the second *spire* coiled under it, the third *spire* passed over the silk and the fourth again under it and so on until the whole surface was thus covered

with one <*coating*> thickness of wire. The whole was again varnished and covered with ribbons of silk. A second thickness of wire was then coiled on in the same manner as the first and so on until the operation was finished, care being taken to have the varnish well dried before winding on the several layers of wires. This process was a very tedious one and occupied myself and two other persons every evening for two weeks. It is one however which will insure success if other circumstances are favourable. The iron is intirely covered in the above manner with four thicknesses of wire and near the ends with five. There are in all 30 strands each 35 feet long so that exclusive of the projecting ends there are about 1000 feet of wire actually coiled around the magnet. In the construction of a large magnet of this kind much caution is required in arranging the several wires so that the galvanic current shall pass through none in an adverse direction and also that two projecting ends belonging to different poles of the battery do not project from the magnet from the same point for in this case the galvanic current will have a strong tendency to pass directly from one wire to the other without making the intire circuit of the wire around the magnet and these conditions you will observe it is somewhat difficult to fulfil when as in the present case there are 60 projecting ends. By not attending to these particulars in one instance a magnet which was partially wound for me by a mechanic entirely failed. You will probably think me unnecessarily minute in my descriptions but

I have thought it best to err on the safe side even at the hazard on your time with much that is perfectly obvious to you.[5]

The construction of the battery will be evident from inspection and therefore requires but little description. It may perhaps be necessary to mention that it is intended to have the zinc separated from the copper by wooden wedges driven in at the *top* and not at the *bottom* and these should not be more than two inches long; with this construction the battery can be nearly all immersed without wetting the wood with the acid which causes a slight galvanic action to be continued after the acid is withdrawn and which in some experiments is very inconvenient. The zinc cylenders of the battery are formed of thin plates of sheet zinc soldered together as to form two thicknesses. You can have these replaced in proper time by cylenders of cast zinc but I do not think from my own experience that the galvanic action continues as long from a piece of cast as from a plate of rolled zinc. All the wires[6] as you will see from the magnet are connected together into two poles by means of two slips of copper; on one of these I have scratched a *C* and on the other a *Z* indicating to which pole of the battery the copper slip is to be soldered. It is necessary to be particular in attaching these in their proper order as from the circumstance of the hardness of the iron it has acquired a perminent magnetism the polarity of which corresponds to that induced by the action of the galvanic current when the battery is attached as I directed. You will also notice two thimbles soldered one to each pole of the battery. These are intended to be filled with mercury after being amalgamated with a solution of the nitrate of the same metal and to receive the poles of a second battery which is necessary in the experiment of changing the polarity of the magnet. For immercing the battery into the acid I use a common earthen ware jar or *crock* which should be of sufficient depth to allow the cylender to be intirely submerged; it may for convenience be suspended by pullies and counter weights. For a plan of a frame for suspending the magnet with a scale and steelyard attached I must refer you to my paper in the 19th vol of the Jour. of Science.[7] The method of exhibiting the power of the magnet is very simple except in the case where it is required to show the absolute *maximum* of magnetic intensity which the iron is capable of receiving; in this case particular attention must be paid to every circumstance which will in the least affect the result. 1st the Acid should be of such a strength and

[5] In the manuscript, this sentence appears in the left margin of the second page.

[6] i.e., "30 strands," forming as many parallel circuits.

[7] "On the Application of the Principle of the Galvanic Multiplier to Electro-Magnetic Apparatus, and Also to the Development of Great Magnetic Power in Soft Iron, with a Small Galvanic Element," *Silliman's Journal*, 1831, *19*:400–408.

quality as to act powerfully and suddenly on the zinc. Mr. Sturgeon[8] reccommends nitric acid with six or eight times its weight of water only. 2nd the battery should be new although not covered with the oxide attached to the surface of sheet zinc as it is found in commerce. 3rd it should not be immersed into the acid 24 hours previous to the experiment or I mean to say that the experiment should not be tried until after the battery has reposed that length of time. 4th care must be taken that the face of the armature and the extremities of the magnet are perfectly clean and free from rust. 5th the stirrup which passes over the armature should rest on the middle of the ridge of the armature and so placed as not to touch the sides when the weight comes to bear upon it. 6th the scale beneath the magnet must be loaded with nearly as much weight as you suppose [the] magnet will carry.[9] A sliding weight of about 30 lbs[10] must then be placed on the lever which can be quickly moved from one end of the bar to the other. To estimate the power more minutely a second sliding weight can be used of about 10 lbs or less. 7th when everything is thus arranged the whole weight should be raised by two men lifting at the longer end of the lever, a third person attending [to] place and hold the armature in its proper position and a fourth to raise the jar of acid. At the given word the battery must be suddenly and entirely immersed, the weight quickly although gently lowered so as to bear on the stirrup. The sliding weight must then be quickly placed on the lever close to the magnet and afterwards moved successively towards the farther end until the pressure becomes too great for the power of the magnet and the whole falls. The last position of the sliding weight by allowing for the leverage, with the weight on the scale, gives the *maximum* of magnetic power. It must be reccollected that the greatest effect is produced at the first moment of immersion and consequently the experiment should only occupy if possible a few seconds of time.[11] In observing all the precaution above enumerated I succeeded in making your magnet sustain for a few seconds and with the smaller battery first used 1700 lbs. By employing the larger battery which I send attached to the magnet its power is increased at least 500 lbs. I have determined this not by actual experiment with weights as in the former case but by means of a *magnetom-*

[8] William Sturgeon (1783–1850), lecturer at the Adelaide Gallery in 1832, electrician, inventor, and author whose publications, electromagnetic experiments, and soft-iron electromagnet interested and influenced Henry. In his own writings, Henry sometimes referred to Sturgeon's work, and the Henry Library contains a complete set of Sturgeon's *Annals of Electricity, Magnetism, & Chemistry; and Guardian of Experimental Science*, the first English journal specializing in electrical subjects. Sturgeon will appear in subsequent volumes of the Henry Papers. *DNB*.

[9] In his draft, Henry wrote "3/4 or more of the weight calculated to be lifted."

[10] Henry suggested a sliding weight of "about 20 lbs" in his draft.

[11] The draft reads "1/2 a minute or even less than this if possible."

eter[12] which I have lately applied to such investigations. I was much disappointed in its not producing a greater effect in the first instance as the insulation of the wires was more perfect than in any other I have constructed and the wires [?more numerous] but the effect is explained by the hardness of the iron which requires a larg[er] quantity of Galvanism to develope in it the same intensity of magnetism than a softer piece of iron. This magnet from the same cause retains the magnetism more powerfully and longer after the acid has been withdrawn than any I have before constructed. In one case the armature could scarcely be removed by the hand after it had adhered more than a month from the time of the excitation and it will continue to support several hundred pounds for some time after the acid is first withdrawn from the battery.[13] I have noted in this magnet a very singular circumstance which arises in part from the hardness of the iron. It is this: the magnet possesses a permanent polarity which has probably been communicated to it by constantly exciting it with galvanic currents from the same battery in the same direction; now when I have changed the polarity by using a small battery containing about ½ foot of zinc this change is not perminent but on withdrawing the battery the magnet spontaneously resumes its former polarity as if this second polarity was only superimposed upon the first.

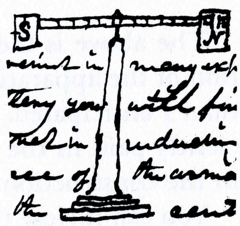
To exhibit the lifting power of the magnet to a class I find the following method the most convenient. The scale is first loaded with about 12 or 15 hundred pounds or the amount of weight the magnet will redily sustain without any very particular precautions. This is raised by means of the lever and the battery entirely immersed and kept immersed until all have seen that the magnet fairly supports the weight. The acid is then slowly withdrawn and the whole weight suffered to fall. Pieces of plank or timber should be placed on the floor so that the fall may not be more than 5 or 6 inches. If a greater effect be required and the action to be continued for some time it will be necessary to employ a larger battery and to immerse this but partially at first and gradually let it into the acid so that while the power decreases in the part [first] immersed a fresh portion will continually come in contact with the acid, but I presume your class will be sufficiently gratified in seeing it support 15 hundred.

To show the experiment of the instantaneous change of polarity a second battery containing about a foot or more of zinc must be attached by means of the thimbles of mercury in such a manner that the galvanic cur-

[12] An instrument for measuring magnetic intensity, especially of the earth's magnetic field.

[13] The last two sentences in this paragraph were added by Henry in the left margin of his letter.

rent from it may circulate in an oposite direction to that from the battery permanently attached to the magnet. Let the armature be loaded with two or three hundred pounds and the magnet excited by the second battery while the weight is supported. Let an assistant quickly raise the jar containing the acid so as to immerse suddenly the first battery at the same instance you withdraw the poles or wires of the 2nd battery from the amalgamated thimble. When this is properly managed the weight will continue to adhere although there is a moment of time when the horseshoe is devoid of magnetism. To render the fact of the actual change of polarity evident to a large class I place two magnetic needles one on each side of the legs of the magnet and these at the instant of the change of polarity turn half way round and present their oposite poles to the magnet. I find it most convenient to make these needles of pieces of watch spring tied together (but first magnetized separately) with a small brass cap between them. They are supported on a stand with a fine sewing needle as the pivot and a piece of thin card is attached to each pole with *N* on one and *S* on the other. Thus: These needles are about 10 or 12 inches long and are very convenient in many experiments on magnetism and electro-magnetism. In the box containing the battery you will find two pieces of round iron. These are for showing the power of the magnet in inducting magnetism in soft iron. The[y] must be placed upright on the face of the armature at such a distance from each other that their axis may be on the centre of the faces of the legs of the magnet thus. While in this position immerse the battery and the two pieces of iron will adhere to the magnet and the armature to them so as to make the whole nearly as sollid as one piece.[14] If you use the magnet for touching bars of steel they should be placed in contact *<and removed>* before the battery is immersed and withdrawn before the battery leaves the acid. In this way I have magnetized to saturation in almost an instant a bar nearly ½ an inch thick [. . .] broad and 16 inches long.



The following is the cost of materials and making not including anything of course for my own labour or superintendence.

Messrs Townsends[15] bill for forming magnet:

[14] The text of Henry's draft ends at this point, although he did append an abbreviated statement showing the total cost of the magnet.

[15] Isaiah and John Townsend, proprietors of a local iron manufacturing firm. See Penfield and Taft to Henry, May 30, 1831, footnote 2, above.

80 lbs at 12 cts	$9.60
Finishing do	6.00
2 pieces round iron	
12 inches	1.53
Filing do	.50
Mechanics labor winding	
varnishing etc.	12.00
Copper wire	8.00
	37.63[16]
battery double zinc plates	6.00
Silk and varnish	1.50
Boxes, packing & cartage	1.00
	46.13

The above is the actual ammount of my expenditures in the construction of the apparatus. The bill of iron and finishing was somewhat greater than I anticipated. With regard to my own labour I consider myself sufficiently paid in the additional knowledge and experience I have acquired in the construction [and] use of the instrument.

You can inclose the amount for the magnet say $45 in bills of the United States bank. I presume they will come safe to hand.[17]

I am with much Respect
your &c
Joseph Henry

[P.S.] In the experiment of the change of polarity I have produced the effect of transmitting a current through a long ribbon of copper from the further end of the lecture room. Please write me if you receive the magnet safely and what success you have in experimenting with it.[18]

[16] In the original, Henry's invoice and explanation of the charges are crowded into two columns, the first ending with the subtotal of $37.63. At the start of the second column, Henry repeated the subtotal ("Amount brought up 37.63") and added the charges below to arrive at his final figure.

[17] Having exhausted the space available to him on both sides of the sheet, Henry turned to the first page of his letter and penned this sentence and the one preceding it in the left margin.

[18] Found on the reverse side of the final page of the letter, this postscript appears as two sentences in block form, separated by the date, above Professor Cleaveland's file notation.