Correspondence.

The Maximum Electric Current.

To the Editor of the Scientific American:

In many of our text books on physics and electricity we find stated, but not proved, the fact that the maximum electric current, obtainable from a given number of cells, is got when they are so arranged that the internal resistance of the battery is equal to the external resistance of the circuit.

This is quite a stumbling block to the student who is not familiar with the solution of maxima and minima problems. Nevertheless it admits of an easy algebraic solution, which has been useful to me in the lecture room, and which I therefore send you, hoping that it may interest some of your readers.

The cells of the battery are to be set up in columns and rows, each column containing the same number of cells all united in multiple, and finally all the columns, each of which acts as one large cell, united in series.

The symbols used in the solution are to be interpreted as follows:

C = strength of current in amperes.
e = electro-motive force in volts of a single cell.
r = internal resistance in ohms of a single cell.
R = external resistance in ohms of the circuit.
p = the number of cells in each column.
q = the number of columns.
pq = the total number of cells in the battery.

The strength of current will, therefore, in accordance with Ohm's law, be represented by the following equation:

$$C = \frac{qe}{\frac{qr}{p} + R} \qquad (1)$$

in which qe represents the electro-motive force, and $\frac{qr}{p}$ the internal resistance of the battery.

The problem is now to prove, with p and q both variables, but so related that their product, pq, is constant, that C has its greatest value when $\frac{qr}{p} = R$.

Equation (1) may be written thus:

$$C = \frac{pqe}{qr + pR} \qquad (2)$$

in which, since e and the product pq are both constant, the numerator pqe is constant, however the values of p and q, owing to different arrangements of the cells, may vary. Thus C will have its greatest value when the variables p and q are so related that the denominator $qr + pR$ has its least value. But

$$qr + pR = \sqrt{(qr - pR)^2 + 4pqrR} \qquad (3)$$

in which, since r, R, and the product pq are constant, the term $4pqrR$ is constant, and the term $(qr - pR)^2$ positive, whether $qr - pR$ be positive or negative. Therefore the radical and its equal $qr + pR$ have their least values and the current C its greatest value when q and p are so related that $qr - pR = 0$.

Or, transposing and dividing by p, when

$$\frac{qr}{p} = R \qquad (4)$$

That is when the internal resistance of the battery is equal to the external resistance of the circuit.

Usually, however, r and R are so related that, with a given number of cells, equation (4) is impossible; but no matter what the number of cells, nor what the relation between r and R, it is evident from equation (2) that C is greatest when $qr + pR$ is least, and from equation (3) that $qr + pR$ is least when $qr - pR$ is most nearly equal to zero; that is, when $\frac{q}{p}r$, the internal resistance of the battery, is most nearly equal to R, the external resistance of the circuit.

We thus arrive at the general conclusion that the maximum electric current obtainable from a given number of cells in a given circuit is got when the cells are so arranged that the internal resistance of the battery is as nearly as possible equal to the external resistance of the circuit.

W. J. HUMPHREYS, *Prof. of Physics.*
The Miller Manual Labor School of Albemarle.

Induction Coil for Alternating Currents.

To the Editor of the Scientific American:

On reading the article "An Induction Coil for Alternating Currents" in the last issue of your paper, March 11, 1893, I was very much surprised to find an accurate description of an instrument in use at the Jefferson Physical Laboratory at Harvard College. The instrument was made by Prof. John Trowbridge about ten years ago, and has been used by him on his class lecture table ever since.

The writer of your article, a Harvard graduate of the class of 1891, is an assistant in chemistry at the Chicago University, and having need of such an instrument as he describes, he attempted to reproduce the one he had seen in the Harvard Laboratory. As his attempt was unsuccessful, he wrote to Prof. Trowbridge, who furnished him with the description and dimensions that appeared in your last issue. The second attempt to reproduce Prof. Trowbridge's piece of apparatus was not wholly successful, on account of the builder's limited knowledge of the induction effects of periodic currents. He again wrote to Prof. Trowbridge, and was furnished with the explanation of these effects and the method of obviating them, as they appear in his article.

The article in your paper was practically made up from Prof. Trowbridge's letters. Prof. Trowbridge, however, informs me that this form of induction coil for alternating currents, with the secondary coil built up about the center of a long primary coil, was first devised and used by Prof. Rowland, of Johns Hopkins University.

TOWNSEND H. SOREN.
65 Thayer Hall, Cambridge, March 16, 1893.

The Elliptical Sprocket.

To the Editor of the Scientific American:

Being somewhat interested in your reply to your correspondent on the elliptical sprocket for bicycles, I will give you my experience and will ask you another question. For the past three months I have been using one, and am convinced that there is a gain, and it is quite perceptible in going up grade. Most people have the idea that there is a jerky motion of the pedals when using one of these sprockets. After using one of these a little and then going back to the round, the latter is the one which seems unsteady. In relation to the leg and the body, is this not true? The motion of the leg from the thigh to the knee is an up and down motion, that is from center to center. By the use of an ellipse as applied to the crank axle, is not this motion more steady than a round sprocket would be? Now when using the round sprocket that is the one which seems to me unsteady, and it seems as though there was a back "pull" when nearing the centers.

C. L. BARKER.
Pittsfield, Mass., March 6, 1893.

That 212½ Tons of Pig Iron.

To the Editor of the Scientific American:

I am in receipt of George E. Andrews letter of the 7th inst., asking if it is possible for one man to handle 212½ tons of pig iron in ten hours, and I am not at all surprised that the gentleman somewhat doubts it, and I was inclined to throw the article in the waste basket after writing. But I will say that there was no error in the figures, neither have I forgotten. To do what I did a man must pick up and throw onto a pile about 100 pounds every 6 seconds, and pigs of iron will average about 100 pounds each. If the gentleman will take his watch and count 6 seconds, he will see that a sprightly, strong man can do that.

The question would be, Can a man endure that for ten consecutive hours? This I know that I have done once in my life, but will never try the feat again, nor advise any other to try it. I confess that I never was so used up in one day of ten hours. I did not write the article to boast of what I had done, but merely to show what a man can endure.

J. E. EMERSON.
Beaver Falls, Pa., March 12, 1893.

Notes from the Columbian Exposition.

Ceylon will make a unique exhibit at the World's Fair. The floor of the building it will erect will consist of Ceylon woods. The pillars, capitals and carvings will all be reproductions of original objects in the ancient cities of Ceylon, and these will all be worked in ironwood, ebony, and satinwood. The gradations of coloring in the carved pillars will be striking. The shading is from pale crimson-yellow of satinwood to the warm orange-brown of the jakwood and the darker tints of margossa, palu and kumbuk. Suriyamara and old root-stem wood of the tamarind are beautiful in the markings. Abundance of light to reveal the beauties of carvings and traceries in the building is to be secured by a large number of windows with beautifully carved frames. One of these window frames will be a reproduction of the stone window from the palace at Yarahu. The building is to cost about $30,000.

The Columbian Rolling Chair Company is now engaging college students for attendance in charge of the chairs. The rates fixed by the Exposition authorities are as follows: For chair carrying one person, 75 cents per hour, 40 cents per half hour; two persons, $1 per hour, 50 cents per half hour; one person, when chair is taken for a period of not less than 10 hours, $6 for the first 10 hours, and 40 cents an hour for the time over 10 hours; carrying two persons, $8 for the first 10 hours and 75 cents an hour after that. In employing men as attendants for the chairs, the company are following the instructions of the Exposition authorities in giving the first chance to college students. The roll will be completed March 1, and 1,600 men will then be employed to report for duty May 1. The attendants will be furnished with comfortable lodgings near the Fair grounds, free of charge, and will be paid 25 per cent of their gross earnings, or will be paid $1 per day and 10 per cent of their gross earnings. The chairs will be mounted on bicycle wheels, with 1½ inch rubber tires and full ball bearings, and will be the only vehicles allowed in the Exhibition buildings.

There is to be a monument of coal at the World's Fair 50 feet high, 10 feet square at the base, and 4 feet square at the top. It is to be exhibited by a Pennsylvania coal company. It will be constructed in sections 16 feet long, and put together at Chicago. Pieces of coal will be selected that will show, when placed in position, all the connecting minerals that are found in the mining of coal. Some parts of the coal will be left in the rough state and others will be highly polished. One single piece of coal already prepared weighs almost two tons.

Apropos of the cost to visitors for seeing the sights of the Exposition, including the entrance charge of 50 cents, a writer in the Chicago *Inter-Ocean* expresses himself as follows: "In the whole length and breadth of the Plaisance are to be about fifty concessions. They include everything, from an electric tower, where a sightseer is asked to pay a dollar for a ride, to the street in Cairo and the Turkish mosque, where the prices are graded from a dime to half a dollar, according to the anxiety of the visitor and the number of sights he sees. Beginning at the east end of the Plaisance, one may pay to walk into the Irish village and see the natives make butter and lace; then he may step over to the electric tower and pay for a ride to the top and back. With his head whirling and his pocket book getting dizzy, he can come to the Bohemian and American glass factories, and pay a quarter for a peep at the blowers. Then he comes to the animal show, and drops half a dollar to see dogs ride tigers and lions draw a cart. If these leave him unsatiated, he can find two panoramas, a Turkish village with dancing girls, a minaret tower filled with curios, a street in Cairo—more dances—a Moorish palace and restaurant, the Algerian section, the Ferris wheel, the ice railway, an old Pompeian house, a Morocco section with balloon attractions, and an Austrian village, and last, a village of Amazons from Dahomey. Each of these has its special features, to which admission is charged by authority of the Exposition. In most cases the fee is 25 cents, in some it is as low as 10 cents, and in others as high as $1. In all cases the Ways and Means Committee derives a revenue of from 20 to 70 per cent of the gross receipts." Finally he arrives at the conclusion that with economy the whole may be seen for $15.

The cars for the intramural elevated railroad at the World's Fair grounds will be 45 feet 11¼ inches long over the platforms, 8 feet 6 inches wide, and have a seating capacity of 70. The seats are fixed back to back and extend entirely across the cars, as in the ordinary open street cars. The sides of the car are closed for a height of about 3½ feet, or to the tops of the backs of the seats, and are provided with sliding doors or gates for ingress and egress. Above this the sides are open, but are fitted with drop curtains to protect the passengers from the sun or rain. The running gear is almost a duplicate of the Manhattan and Chicago elevated trucks. The cars are equipped with the New York Air Brake Company's special brake for high speeds, and the first train of cars having been completed, tests of the apparatus will be made in Chicago in a few days. The motive power of the road is to be electricity. The motor car carries passengers and in many respects is a duplicate of the others. In addition to the motors for hauling the train, it has an air pump operated by an electric motor. The brakeman stationed on the end platform of the car controls the hand brakes, the roller curtains and the gates. The cars weigh about 2,200 pounds and are lighted by electricity.

Leaky Roofs at Chicago.

Director-General Davis has issued an order to release no more exhibits from bond at present. Cars loaded with goods from foreign countries were stopped on the tracks at the entrances to several buildings. Customs inspectors were cautioned not to allow the seals to be broken and to hold the cars until further notice.

This order was the result of protesting against the leaky roofs of Manufactures, Agricultural, and Transportation halls by the foreign commissioners, many of whom had commenced to unpack their displays. They told Colonel Davis that their exhibits would be ruined if exposed to the rain that ran in torrents through the roofs, and demanded that the leaks be stopped at once, that they might go on with the arrangement of the displays.

The roof of Manufactures Hall is in a very bad condition. The construction department has not been able to make repairs since the snow slide crushed the skylights, and water rushes through in cascades. With the exception of several sections the floor was completely drenched lately. In some places water stood in pools an inch deep. The exhibitors of half a dozen foreign nations and many Americans were compelled to quit work.

THE order has been given that all the portraits taken in her Majesty's prisons, as records of crimes and criminals, shall for the future be printed only on platinum paper, the object being to secure their permanency.