in diameter, in three pairs, connected by heavy expansion gearing at each end of the rolls. The rolls and upper cylinder can be elevated to take in lumber five inches in thickness. The upper rolls of the contiguous pairs are adjusted simultaneously by means of a hand wheel with geared connections.

The under cylinder is adjustable vertically for graduating the thickness of the cut, and is placed so that the discharging rollers carry the lumber from it. This is a novel and distinguishing feature of this planer, the rolls through which the lumber last passes being placed outside of the under cylinder and bending pressure bar, which is placed and adjusted over the under cylinder.

These rolls are usually placed in the machine so that the under cylinder does not commence cutting until the board has passed some distance through, and consequently a portion of the board must depend upon being driven over the under cylinder by the board following. This defect is obviated by the new position of the cylinder and the discharging rolls.

Accessibility to the under cylinder is facilitated by the method adopted of moving the discharging rolls by revolving the end of the machine supporting them upon a hinge in one side of the frame; and the pressure bar over the under cylinder, being revolved upon one of its supports, leaves the under cylinder entirely open for any purpose of adjustment the operator may desire. The side cutterheads, being adjacent to the under cylinder, can also be more readily adjusted by virtue of the position thus attained.

This arrangement is a very desirable one, and the end of the machine is claimed to lose none of its stability, as the supports are of the most permanent character, easy of access and attached or detached very quickly.

The lower roller on the movable end of the machine has a vertical movement to compensate for any changes in elevation of the under cylinder, and in order that a constant pressure may be retained upon the lumber by keeping the peripheries of the cylinder and roller in the same relative position.

One of the machines may be seen on exhibition in daily operation in Machinery Hall, section B 8, columns 61, 62, 63, Centennial Exhibition, Philadelphia, or further particulars can be obtained by addressing the manufacturers at Cincinnati, Ohio.

[For the Scientific American.]

THE EXHIBIT OF CORNELL UNIVERSITY AT THE CENTENNIAL.

In the account of technical schools recently published in the SCIENTIFIC AMERICAN, the exhibit of the mechanical engineering department of Cornell University was omitted, as the articles shown by this school are of such an interesting character as to warrant a separate description.

Cornell University, as most of your readers doubtless know, furnishes courses in almost every branch of learning; but the present notice must be confined to the practical part of the course in mechanical engineering. This course covers a period of 4 years, during which each student is required to work for 10 hours a week in the shop. Some of the results of this work are shown at the Centennial, and the visitor is not deterred from making a critical examination by notices that handling is forbidden, but, on the contrary, is invited to subject the articles to any test that he may desire. Some surface plates, placed upon a low table, are particularly inviting to the passing visitor, who can make one plate float upon the other, and, after working out the air between, can lift the pair by grasping the upper one. These surface plates are a regular article of manufacture at Cornell University, and are sold at such a reasonable price (10 cents a square inch) that it is a matter of surprise to find that they are not in great demand. The scholars also make steel triangles for the use of draftsmen, and these will be found very serviceable for nice work. Professor Sweet, who is in charge of the practical course at Cornell University, proposes to add, to the articles manufactured for sale, solid calipers, accurately ground to standard sizes, which will be as useful as the well known Whitworth gages, and much cheaper. A necessary machine in connection with this manufacture is an instrument for accurate measurement; and a measuring machine reaching to ten-thousandths of an inch has been made at the school. This is constructed on the general principle of Whitworth's measuring machine, but has some important improvements. The principle of the machine is the same as that of the sheet metal gage made by Brown & Sharp, in which the measuring points are brought together by a screw, and the fractions of the revolution are measured on a wheel attached to the screw. In the machine under consideration, the screw has a pitch of $\frac{1}{16}$ of an inch, and the wheel is divided into 625 equal parts, each of which measures a movement of $\frac{1}{10000}$ of an inch. In the use of a machine of this kind, it is found that, if several operators each measure the same article, adjusting the points by their judgment, their results will vary sensibly; and one of the improvements of the present machine consists in having the handle which moves the screw independent of it, being kept in contact by friction until the measuring point bears against the article to be measured, when it slips. Another important improvement over the Whitworth machine is the use of a short screw, and a nut of the same length. By this arrangement, the motion of the measuring point attached to the screw is only about an inch, but the other point is adjustable on a slide to any desired distance up to one foot, so that the range of the machine is for articles from $\frac{1}{10000}$ to 12 inches, varying by ten-thousandths. A steam engine, built by the students, from Professor Sweet's design, has several novel features. The frame has three supports, the cylinder resting in a socket upon one, and being free to move under changes of temperature. The piston is made very long, and has a number of grooves, no packing being used. The piston rod passes through a grooved tube, without any packing, and the valve stem, also without packing, works through a plain brass tube of considerable length. The valve consists of two flat plates, accurately fitted to the valve seat and an upper plate, thus being perfectly balanced, and being made very thin, to obviate as far as possible the difficulties caused by unequal expansion. The governor is attached to the fly wheel, and is connected with the eccentric, which swings round a point near one edge, under the action of the governor. The effect of moving the eccentric is to change the amount and period of opening of port, while the lead remains practically constant. The eccentric acts on the valve stem through the medium of a bell crank lever, so as to equalize the cut-off at each end of the cylinder. The valve motion of this engine, it will be seen, is quite novel, and it may be illustrated and more fully explained on some future occasion. A model of the valve is shown, with a neat arrangement for tracing a diagram of its action. The crosshead of the engine is unusually long, and the connecting rod, instead of vibrating on the pin, is rigidly attached to it, and the pin moves in bearings on the crosshead. This arrangement greatly facilitates accurate adjustment. The crank pin works in cast iron boxes. The main bearings have considerable side play. It would be impossible, without illustration, to give a thorough explanation of the features which have been briefly enumerated. The design in building the engine was to give the students some idea of the requirements of a good engine. The result is a substantial machine, and one which will probably be serviceable as constructed at present, though it will be noticed that some of the details are experimental. It will be easy, however, to use packing, if it should be found necessary. The engine has a diameter of 6 inches and a stroke of 12, can be run at a speed of 300 revolutions a minute, and will be sold for $750.

If any of your readers is looking for a complete foot lathe he will do well to visit this exhibit. The amateur foot lathe made by the students, is the second that has been constructed at their shop, and seems to be as nearly perfect a machine of the kind as is usually met with. It has a 4 foot bed and 10 inch swing. There are three speed wheels for the driving belt, an internal back gear on the head stock, three friction feeds, and change wheels for cutting screws of 26 different pitches. The machine is adapted to all kinds of work that can be done on a lathe, straight and taper work, turning spheres, etc. The slide rest moves on one flat and one V way. There is an adjustment for a slight movement of the tool, such as may be required in screw cutting. One wrench fits all the nuts which must be loosened to make adjustments. Handles are fitted to all parts in which frequent changes are required. The rock shaft of the treadle motion works on knife edges, and requires no lubrication. On removing the foot from the treadle, it becomes detached from the pin of the connecting rod, and is caught and held up by a spring. There are drawers at the back of the machine for the extra wheels and tools. This machine is offered for sale at the very moderate price of $400. It is probable that it will be bought by some amateur who knows how to appreciate work of this kind.

The engine in this exhibit drives a Gramme machine, which has the power of a Grove battery of 100 cells. This machine was built by the students, from designs furnished by the Professor of Physics, and is, so far as the writer knows, the only machine of the kind built in the United States. It furnishes power for several electric engines used by another exhibitor for driving a lathe, a sewing machine, and a mill, also for an electric light, and for burning wire. The machine has several ingenious adjustments or switches by which the direction and quality of the current can be changed, and it can also be used as an electric engine, driven by a battery.

Philadelphia, Pa. R. H. B.

[For the Scientific American.]

THE FACTS OF THE LAWS OF GRAVITATION.

The crucial test for the correctness of a scientific theory is the inquiry whether it will enable us to predict phenomena, and whether experiment or observation will verify every prediction. Recently a member of the French Academy stated that he had conceived a new theory of electricity, and was at once asked if it had enabled him to foresee phenomena, and if he had found practically the verification of his prediction. His answer was affirmative, but not as positively so as strict science requires, and his theory is therefore still an hypothesis.

Among all the scientific theories, there is none more firmly established than that which maintains the universality of gravitation, and establishes the laws governing it. We avoid speaking of a theory of gravitation, because we cannot help considering gravitation as a stubborn fact, and not as a mere speculation. That bodies fall to the ground, and after having falling exert an amount of pressure on their support in proportion to their mass, is a simple, universally recognized fact, without any theory about it; and this is what we call gravitation, which means simply that matter is heavy, and that twice or thrice the mass is twice or thrice as heavy. But the laws which govern gravitation, the universality of its action, and its presence throughout the whole Universe: these form a theory, which is susceptible to proof.

If ever any scientific theory was thoroughly tested, by predictions of phenomena expected under certain circumstances, it is this; and if ever any theory was fortified by the subsequent observation and verification of the predicted phenomena, it is this. It has been attacked in some quarters, even by persons of education, and doubts have been thrown upon its teachings. This was done by the great German poet and philosopher Goethe, among others; but he was simply ignorant of the facts. Every man judges about things according to the amount of information in his possession; and if Goethe had been informed of the manifold facts verifying this theory, he would surely never have attacked it. Unfortunately he did not know anything about mathematics, which is the science of the laws governing space and time, and therefore the key to all natural philosophy; neither had he ever received any training in practical observation and experiment, his large treatise on optics being a gigantic confession of ignorance of the subject, and also of his inability to draw correct conclusions from phenomena observed. He erred equally when treating of gravitation; he showed that he had not the least comprehension of the established theory, forgetting, as he did, that, in order to criticize anything thoroughly and successfully, we must first understand it well. Hence his strictures upon the Newtonian theory go for nothing, and have weight only among those who know as little about it as Goethe did; and their number is, unfortunately, not inconsiderable.

Newton tested his theory by the motion of the moon, and found that, if terrestrial gravitation (which is no theory, but a fact) extended to the moon, and diminished inversely as the square of the distance from the earth's center, it would, as the moon is at a mean distance of 60 terrestrial radii, be 60 x 60 or 3,600 times less in power on the moon. As a body on our earth falls nearly 16 feet in the first second, it would, at the distance of the moon, fall 3,600 times as slowly; and as an hour is 3,600 seconds, it would there fall in an hour no further than near the earth's surface in a second, so that the moon falls every hour 16 feet towards the earth. Comparing with this figure the tendency of the moon to move in a straight line, as is the natural property of all moving bodies, and the moon's consequent tendency to fly off in a straight tangent from its curved orbit, he found that, if terrestrial gravitation or attraction were withdrawn, she would in an hour be 16 feet further from the earth, this centrifugal force appearing exactly to counterbalance the terrestrial attraction at that distance, and proving that it really was 16 feet for the first hour: verifying thus the law that the attraction is inversely proportional to the square of the distance.

That this terrestrial attraction or gravitation was partially counteracted, even on the earth's surface, by the earth's rotation around its axis was proved by the fact that this attraction was stronger near the poles, where the circle of rotation is smaller and the velocity less, and weaker under the equator, where the circle is larger and the velocity greater; while in the latter case the centrifugal tendency is in a direction exactly opposite to that of gravitation, so that bodies weigh more at the poles than near the equator.

That the terrestrial attraction is not a property of the earth, but is diffused throughout all matter, so that all bodies attract all other bodies, was proved by the torsion balance of Coulomb, by which he proved that a heavy mass, suddenly brought before a small ball delicately suspended in a glass case, will attract the latter from its position; he even measured the amount of this attraction for masses of a given weight, and in this way came, by comparison, to the knowledge of the mass of our whole earth.

That the terrestrial gravitation is not concentrated in the earth's center, but a resultant of the sum total of all the individual attractions of every particle contained in it, is proved by the diminished gravitation when descending in a mine. If indeed the attraction solely resided in the center, it should increase when going down; but being a result of the attraction of the whole mass, the central attraction is counteracted by the attraction of all masses above the observer; and hence gravitation decreases with the depth, and if it were possible to reach the earth's center it would be found there to be zero, the attraction being balanced all round.

In Herschel's "Astronomy," published many years ago, an arrangement is suggested for observing the difference in gravitation on the earth's surface, by counteracting it by a force not dependent on gravitation, namely, a spiral steel spring. It is evident that, if we wish to ascertain whether a mass of say 1 lb. in weight, weighs less under the equator than near the poles, we must not use a 1 lb. weight as counterpoise, as this would be equally affected by the terrestrial attraction; but if we use a spring to suspend it from, we shall observe less tension in the spring on which the mass of 1 lb. is suspended when brought to a locality where the gravitation is less, as is the case under the equator, than it is at the poles.

The apparatus suggested by Herschel is but a rough contrivance, and only fit to show that there is a difference, and it is not adapted to measure the amount of this difference. It consists of a stand from which a spiral spring is suspended, to the lower end of which a weight is attached. The weight and spring are so arranged that, when the whole machine is placed perpendicularly, the weight will just touch a piece of glass plate, inserted in the base under it. If now this apparatus is carefully packed up so as not to disturb anything, and transported to a locality where gravitation is less, it will, when set up again, show that the gravitation is not sufficient to draw the weight down until it touches the glass plate.

Siemens has succeeded in constructing an apparatus, founded on this principle, so perfect that he can measure the diminished gravitation with sufficient accuracy to calcu-