light is weakened, even though its quality remains the same. If, therefore, we suppose that two lights, one red and one blue, appear equally bright when the intensity has a certain value, the blue one will appear the brighter when the intensities are equally diminished and the red one will appear brighter when they are increased. On lowering the brightness sufficiently the blue light will even remain visible after the red one has disappeared.

It will be observed that the Purkinje effect acts in the right direction to explain the observations of Campbell, since it was the blue line $H\beta$ which appeared relatively brighter in the faint parts of the nebula, but it seemed very doubtful whether it was competent to explain the amount of the observed differences. The lines observed by Campbell were not at opposite ends of the spectrum, but were close together, all being in the bluish green. The physiological effect must have been small, yet the observed variations of the $H\beta$ line were as much as 20:1. Careful observations made at the Lick Observatory during the past winter have shown that these variations are in fact real, and cannot be explained on physiological grounds.

The non-homogeneity of the Orion nebula must, therefore, be regarded as proved. The substances (or substance) yielding the chief and second nebular lines are more particularly concentrated in the Huyghenian region; in the faint and remote regions hydrogen predominates.

It may be admitted that this non-homogeneity of the nebula may be only apparent, that the substances of which the nebula is composed may be distributed in the same proportions throughout its whole extent, and on account of differences of temperature, density, etc., the spectrum is not everywhere the same; but the fact remains that the quality of the light emitted by the Huyghenian region differs from that emitted by the outlying parts, as if the materials themselves were distributed in the manner already stated.

When this non-homogeneity of the nebula was discovered, it was pointed out by Prof. Keeler, then director of the Allegheny Observatory, that it would necessarily cause a difference between drawings and photographs; for the light from the diffuse hydrogen streamers, though strongly actinic, would scarcely affect the eye. The nebula is seen by one set of rays and photographed by a different set, so that the two impressions cannot be expected to agree unless these sets of rays are emitted in like proportions by all parts of the nebula. This is not the case; and only the amount of the differences thus produced can be called in question.

Prof. Keeler proposed a method for testing this point, and for producing photographs directly comparable with drawings, which he successfully put in practice last winter at the Lick Observatory. The method consisted in photographing the nebula, through a ray filter or color screen, on an orthochromatic plate. The color screen, which had to be chosen with special reference to the nature of the spectrum of the nebula, was of a light green color. It completely suppressed the entire spectrum of the nebula, down almost to the $H\beta$ line, transmitting, therefore, only the lines which are recognized by the eye. By means of orthochromatic plates sensitive to green light the nebular lines $\lambda 5007$, $\lambda 4959$, and $H\beta$ were rendered with nearly their proper visual relative intensities. The image of the nebula photographed through the color screen, in this way, was therefore practically identical with the image which is seen in the telescope in ordinary observation.

The instrument which was used was the three-foot reflecting telescope already referred to as having been made by Dr. Common. This telescope had come into the possession of Mr. Edward Crossley, of Halifax, England, who presented it to the Lick Observatory; and through the offices of Dr. Holden, the former director, it was transferred to California and set up on Mount Hamilton.

The Crossley reflector is a very effective photographic telescope. The Huyghenian region of the Orion nebula can be photographed on an ordinary plate in thirty seconds, and an exposure of five minutes shows a large amount of the surrounding nebulosity. Nevertheless, so feeble is the actinic power of the rays transmitted by the color screen, that the exposures had to be increased from thirty to fifty times to obtain corresponding results when the screen was used. The correct ratio of exposures having been ascertained by experiment, two photographs were taken on the same night, one on an ordinary plate and the other through the color screen on an orthochromatic plate. In order to secure comparable negatives, the two plates were developed together. A considerable number of such photographs was made.

The result of the investigation was that the earlier spectroscopic observations are confirmed and extended, and that the most obvious discrepancies between photographs and drawings are explained. The photographs taken with the color screen are in much better general agreement with drawings than are ordinary photographs. Thus the Huyghenian region is relatively very strong, while the features which have been referred to as abnormally strong on an ordinary photograph, as, for instance, the nebulosity surrounding the star Bond 734 and the nebulous curves west of the Huyghenian region, are much reduced.

Another example of particular interest is the following: The long, scimiter-like streamer, extending upward (south) from the Huyghenian region, is easily visible in small telescopes. It was discovered by Messier in 1771, and is known as the Messerian branch (see Fig. 1). It is, of course, represented in all the drawings. Just to the left of the Messerian branch, and running parallel to it, is a shorter streamer, which is not easily seen, even with large telescopes, and is not shown on any drawing except Lassell's drawing of 1862. Yet on an ordinary photograph these two streamers have nearly equal strength (Fig. 1). The explanation as given by the orthochromatic photographs is, that the lowest nebular lines are strong in the spectrum of the Messerian branch and very weak in that of the companion streamer.

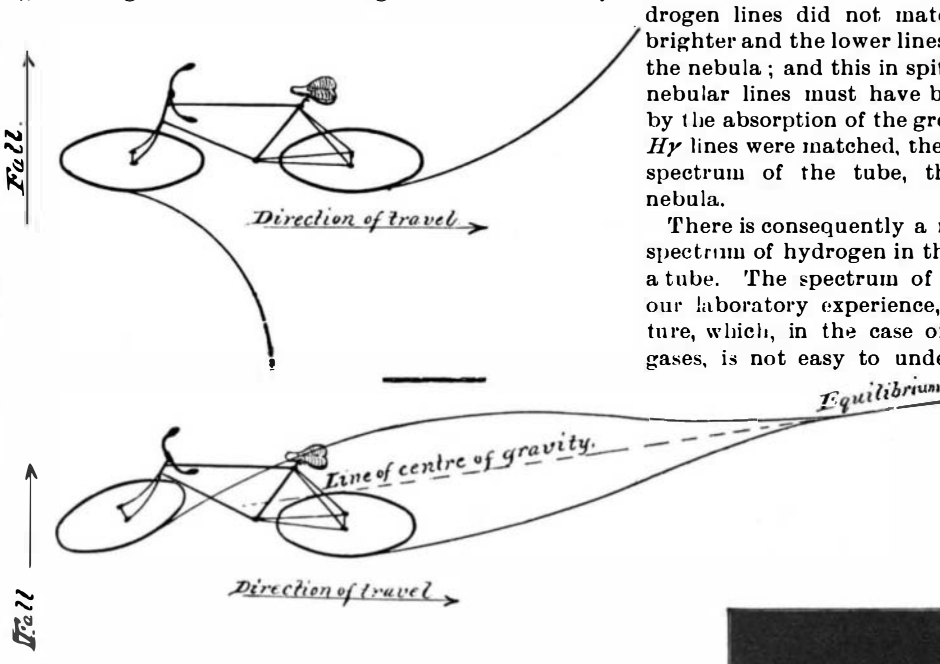
The question has been raised whether the spectrum of hydrogen given by the nebula of Orion is identical with the spectrum obtained from hydrogen in our laboratories, and, incidentally, why it is that the red hydrogen line, $H\alpha$, cannot be seen in the spectrum of the nebula. Prof. Scheiner, of Potsdam, has shown that a hydrogen tube cooled down to —200° C., and excited by feeble electric waves, gives the same spectrum as it does at ordinary temperatures. We cannot suppose, therefore, that the spectrum of the nebula is influenced by the cold of space.

Prof. Scheiner very plausibly explains the invisibility of the $H\alpha$ line as a consequence of the Purkinje effect. A simple observation due to Mr. W. H. Wright, Assistant Astronomer at the Lick Observatory, seems to show, however, that some other than physiological causes are also concerned in this peculiarity of the nebular spectrum.

The great telescope, carrying a spectroscope, was directed to the nebula of Orion, and the light from a hydrogen tube was thrown into the spectroscope, so that the two spectra appeared side by side. The hydrogen tube was mounted on a long slide in such manner that, by simply changing its distance from the slit, the brightness of its spectrum could be altered, while the quality of the light, of course, remained the same. It was thus easy to adjust the tube until any line of the artificial hydrogen spectrum exactly matched the corresponding line in the spectrum of the nebula.

When this was done, it was found that the other hydrogen lines did not match, the upper lines being brighter and the lower lines fainter in the spectrum of the nebula; and this in spite of the fact that the upper nebular lines must have been considerably weakened by the absorption of the great object glass. When the $H\gamma$ lines were matched, the $H\alpha$ line was visible in the spectrum of the tube, though not in that of the nebula.

There is consequently a real difference between the spectrum of hydrogen in the nebula and hydrogen in a tube. The spectrum of the nebula, interpreted by our laboratory experience, indicates a high temperature, which, in the case of such enormously rarefied gases, is not easy to understand. We may suppose that the light of the nebula is excited by electrical disturbances, in which case the temperature of the gases may be low; but of these electrical disturbances we have no independent knowledge. The problem is one of many which still await solution.



Method of Regaining Equilibrium.

Regaining the Balance.

Retaining the True Balance.

The Two White Cords show the Axis of the Head and the Point of Contact of the Wheel.

THE PRINCIPLE OF RIDING THE BICYCLE BACKWARD.

RIDING A BICYCLE BACKWARD.

BY E. J. PRINDLE.

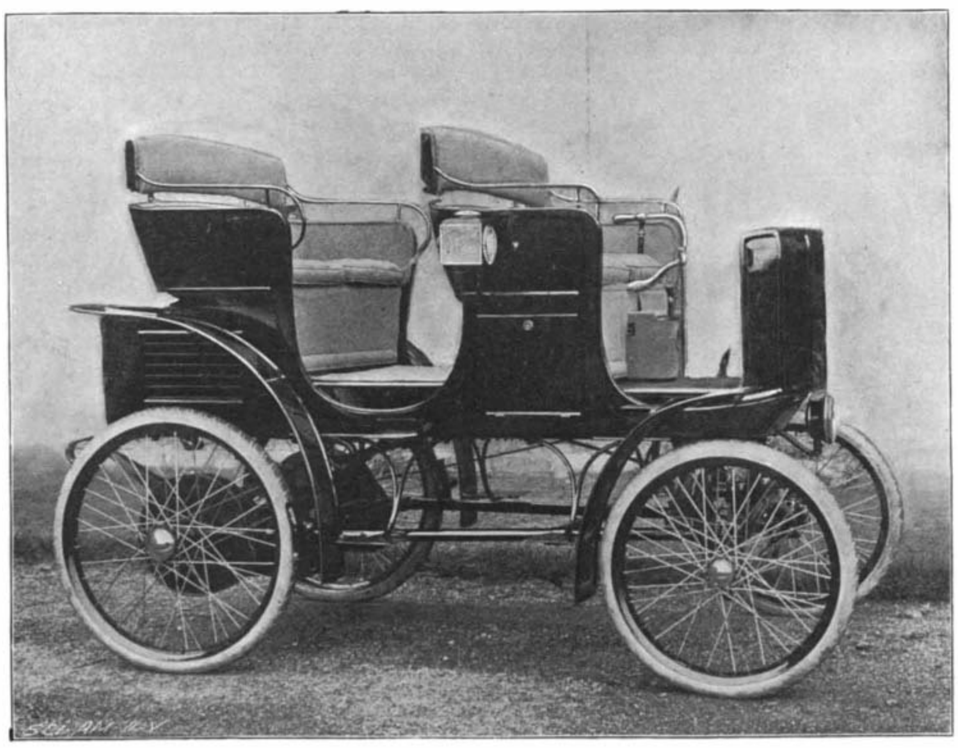
A study of the mechanics of the bicycle is very interesting; for the safety bicycle is a wonderfully perfect machine when considered in relation to the purpose for which it was intended; in fact, it is one of the most perfect solutions of a mechanical problem that has ever been devised. So perfect is the safety bicycle, in fact, that, if the rider has sufficient skill not to interfere with its action, it will travel straight ahead and keep its own balance. The perfection of its design is, perhaps, most easily seen by an analysis of the various ways of riding the bicycle.

To explain the manner of balancing and steering by controlling the front wheel, it is not necessary to go very deeply into the structure of the bicycle. A rider loses his balance when his weight is not over a line connecting the points of contact between the wheels and the ground. To regain his balance, he turns his front or steering wheel in the direction in which he is falling, thus causing the line of contact of the wheels and ground to pass sideways in the direction of the fall until it is again under his center of gravity.

To steer to one side, the rider should throw his weight to the side toward which it is desired to go. The front wheel is also turned in this direction, and the tendency to fall is counterbalanced by the constant travel of the points of contact of the wheels with the ground in the direction of inclination. Equilibrium is thus maintained during the turning. When it is again wished to go straight, either the weight is shifted to the opposite side (by leaning) or the front wheel is turned still sharper, as in restoring the balance.

In examining the mechanics of the more difficult features of bicycle riding, it is necessary to consider with more particularity the laws governing the action of the front or steering wheel. The front wheel is mounted on an axle which supports a fork whose stem has a bearing in a rearwardly inclined position in the head of the frame. The fork curves forward as it approaches the axle. If the stem were vertical and the fork straight, the axis of the stem would meet the ground at the point where the wheel rests on the ground. The inclination of the fork stem, however, causes its axis to pass in front of the point of contact of the wheel and ground, thus producing the effect of the caster wheel, such as is used on furniture. The curve in the fork brings the point of contact of the wheel closer to the axis of the stem, and, without destroying the caster action, increases the sensitiveness of the steering wheel. The chief effect of the caster construction is that the point of contact of the wheel, by dragging behind the axis of the stem, exerts a strong tendency to keep the wheel pointed in the direction of motion of the bicycle.

If the stem axis be kept in the vertical plane through



COLUMBIA TWO-SEATED "SURREY" MOTOR CARRIAGE.

the axle, there is no tendency of the wheel to turn to the side when the stem is inclined laterally. When, however, the stem is not kept in this vertical plane and is inclined toward a given side, the wheel turns toward that side until its axle is in the vertical plane passing through the stem. The reason for this lies in the tendency of every body that is free to move to seek the position in which its center of gravity is lowest. In such a position of the wheel, the distance from its center to the ground is less than its radius.

Applying this law to the construction of the bicycle, the inclination of the stem axis tends, when the frame is vertical, to turn the steering wheel across the frame. As the frame is tipped further the wheel turns toward the front until, when the frame lies on the ground, the wheel is practically in line with the frame. The wheel turns to the side toward which the frame leans, and this is because the axis of the stem, passing to the rear of the axle, leaves the center of gravity of the wheel in its front.

There are, therefore, two forces acting on the unrestrained steering wheel. First, there is the caster action, which tends to keep the wheel in line with the frame; and, second, there is the tendency of the wheel to turn to the side toward which the frame is inclined and throw the axle into the vertical plane passing through the stem axis. The position which the wheel takes is one due to the resultant of these two forces.

In riding straight ahead with the steering wheel unrestrained, if the balance is lost, the steering wheel, owing to the inclination which the stem axis thus receives, turns in the direction of fall and carries the line of contact of the wheels with the ground laterally until it has passed under the center of gravity of the rider and wheel, when the frame either remains straight or inclines in the opposite direction. In the latter event the steering wheel again automatically restores the balance.

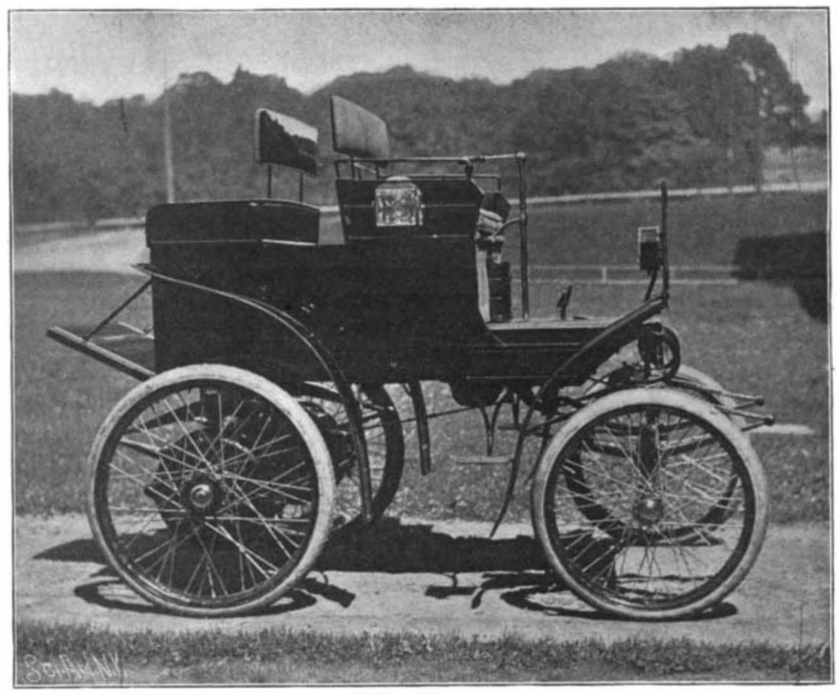
If the rider, when running with hands off, desires to turn to one side, he leans to that side; and the steering wheel turns itself in the same direction. When the turn has been made, the rider leans in the opposite direction until the front wheel has again placed itself in line with the frame.

The acts thus far enumerated are commonly performed; but the feat of riding backward is much more difficult and rare. That this can only be done by manipulation of the steering wheel will be apparent from the following considerations:

In riding backward with the steering wheel free, the point of contact of this wheel drags and seeks to move, relative to the frame, away from the direction of travel. It accordingly approaches the stem axis, turning the wheel across the frame. The steering wheel remains in this position, because it is the position of lowest center of gravity, and because the point of contact cannot go beyond the stem axis. Owing to the position of the center of gravity of the steering wheel in front of the stem axis, the wheel will fall to the side toward which the frame is inclined and will cause the head to run away from the direction of fall, instead of in the same direction as the fall, as it does in riding forward. It is therefore apparent that the bicycle cannot be ridden backward when the steering wheel is allowed to control itself.

Let us see what can be done by manipulation of the steering wheel. If perfect balance could be maintained, the bicycle would travel in a straight line and no trouble would occur. In actual practice, however, the bicycle is always falling either to one side or the other. Suppose it to fall to the right side. The driving wheel, which is now the front wheel, being inclined to the right, will travel in a curve toward the right, as does a coin when it is rolled freely across the floor. The driving wheel is consequently going in the proper direction to carry the line of contact under the center of gravity and restore equilibrium. If, then, we turn the steering wheel so that it travels to the right, the bicycle will travely bodily in the direction of fall, and if this takes place more rapidly than the center of gravity travels laterally, equilibrium will be restored.

The secret of recovering the balance in riding backward lies in turning the steering wheel in the opposite direction relative to the direction of travel of the machine from that in which it is turned when riding forward. Having once learned to turn the handle-bar one way in riding forward, it is very difficult to turn it in the opposite direction merely because the bicycle is traveling backward.



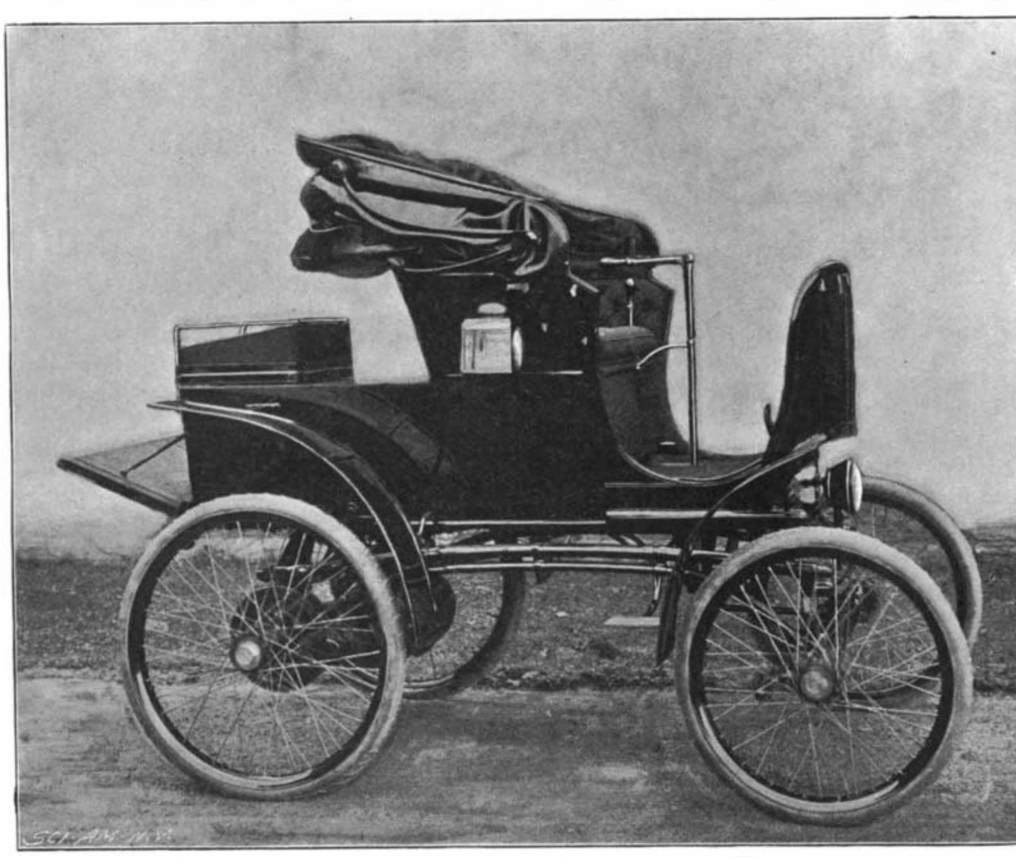
COLUMBIA TWO-SEATED "DOS-A-DOS" MOTOR CARRIAGE.

COLUMBIA MOTOR CARRIAGES.

The three motor carriages herewith illustrated were chosen from the many styles of automobile turned out by the Pope Manufacturing Company as being thoroughly representative of the work done in the motor carriage department of this firm. In every case the motive power is electricity, the company being of the opinion that in the present state of the art electricity, while not without its limitations, fulfills more of the necessary conditions of a successful motive power than the steam or gas engine.

The storage electric motor is clean, silent, free from vibrations, thoroughly reliable, easy of control, and produces no dirt or odor. While it is not so cheap nor of such mileage capacity as some other forms of motor, it is certainly not extravagant in proportion to the service rendered, and its capacity has been proved to be more than equal to the demand of the average city or country vehicle. The greatest demand for an efficient automobile comes, not from people who wish to take long tours through the country, or whose business calls them to any considerable distance from an electric charging station, but from surgeons, expressmen, and those private citizens who wish to keep a carriage, but cannot afford either the space or the cost entailed in providing a team, stable, and coachman.

In order to secure data as to the necessary mileage to be provided for in the storage batteries, the Pope company had cyclometers attached to the conveyances of several individuals who were engaged in occupations in which the automobile would prove serviceable. The investigation showed that the average mileage was 18 miles per day, and except in one case the maximum mileage did not exceed 25 miles. Accordingly, batteries are furnished for the motors that have a capacity of 30 miles per day on level roads and 25 miles on the ordinary grades of a New England city. These figures are, of course, modified by conditions of mud, snow, or rocky roads. The batteries can be charged from any 110-volt direct current circuit such as is used in city lighting. Where current of a higher voltage or the



COLUMBIA DOUBLE-SEATED "PHAETON" MOTOR CARRIAGE.