which even isolated shingle of large size, or small boulders, have been carried has been about three miles, and they are still about fifteen miles from the lake, and with less chance of making even the same progress again, for the creek becomes flatter as it approaches the low grounds. It will be observed, also, that until the whole lake, up to its lowest water-level, has been filled by solid material, its utility for storing flood waters is unimpaired. I am not in a position to state the contents to that level, but taking its depth at five feet—which I believe to be within the mark—it will be granted, I think, that even with much increased diggings it is safe for many years. If not, then the sooner the outlet is raised artificially the better.

But a real argument for a portion, at least, of this work is to be found in the neighbourhood—from the fact that there are now two outlets from the lake proper, while, before the 1868 floods, there was only one; and also the narrow gorge at the foot-bridge was widened by about an eighth part in the flood of 1870, and from the nature of the strata—being basalt, with very many joints, overlying clay—it is liable to greater extension, and, consequently, to allow the water to come more quickly towards the lower parts and facilitate floods. If it should so happen, in succeeding floods, that the same enlargement of these three outlets should continue, the utility of the lake as a regulating reservoir will be very much reduced; and the more rapid delivery of its waters may almost enable a flood equally as destructive as that of February, 1868, to result from less rain.

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Ant. XI.—An Astronomical Telescope on a New Construction.

By H. Skey.

(With Illustrations.)

[Read before the Otago Institute, 19th November, 1872.]

If we take a small plane mirror and reflect a parallel beam of light from any distant luminous object, as the sun, on to any fixed point, and then arrange another small mirror close to the side of it, so as to reflect the light from the sun to the same point as the first mirror, and thus proceed to any extent, arranging a number of such mirrors in one plane, so that they shall all reflect the incident ray to the same point, (Fig. 1. F), then because the angle of incidence of a ray of light is equal to the angle of reflection, the curved line joining the centres of these mirrors forms the arc of a parabola, and each mirror when so arranged is a tangent to this arc, the surface generated by the revolution of such an arc on its axis being termed a paraboloid.
As the rays of light from the heavenly bodies may be practically taken as parallel, it is evident that this is the theoretical figure for the specula of reflecting telescopes, for then only can all the rays of light be reflected to one point (E).

It will be observed that this curve, near its vertex, approaches to, although it cannot perfectly coincide with, the figure of the sphere.

Now as this curve is a varying one it is clear that no grinding and polishing can mathematically produce the parabolic figure; but as the curve in a sphere is invariable, therefore the spherical figure is first imparted to the ordinary speculum, and this is then modified empirically so that it shall approach to the parabolic figure.

In this manner specula have been constructed whose diameters equal one-sixth of their focal length, but as the parabolic curve rapidly departs from the spherical it is evident that reflecting telescopes of large aperture on the ordinary construction must be of great length and cumbersome in their management. There is also a difficulty in giving them a perfect and durable polish, and then mounting them so that they shall neither be affected by changes of temperature nor deflection of different parts, from their great weight.

The telescope here described has been constructed with a view of surmounting some of these difficulties; its speculum may be said to be cast in Nature's mould, as its figure is determined by the action of those "Laws of Motion," the truth of which were enunciated, and their universality demonstrated by Newton.

Let any liquid be rotated in a vessel, with a given velocity, on an axis which has been adjusted perpendicular to the horizon. After a short time all the forces will be in equilibrium, and the fluid will assume a fixed position. As the surface is free to move, it must, at every point taken upon it, be perpendicular to the resultant of the forces acting upon it at that point.

Let the curved line (Fig. 2) be a section of the rotating surface made by a plane passing through NV, the axis of rotation.

Let P be any point taken on it. If PM be drawn at a right angle to the vertical axis NV, it is evident that during the motion of the point P will describe a circle in a horizontal plane whose centre is M. In consequence of this circular motion, a centrifugal force will be developed, pressing against
the surface in the direction PC. Let \(\text{PC}\) represent this force; but \(\text{P}\) is also subject to another force, namely, its own weight acting vertically downwards, which we may suppose represented by \(\text{PQ}\); the resultant of these, therefore, \(\text{PR}\), is the whole force acting on \(\text{P}\), and so must be perpendicular to the surface, and therefore to the curve. To prove that this curve is parabolic—

\[
\text{NM} : \text{MP} :: \text{PQ} : \text{QR} (=\text{PC}).
\]

\[
\text{NM} : \text{MP} :: \text{Weight P} : \text{Centrifugal force}.
\]

But the dynamical measure of the force of gravity at this latitude is 32-17, expressed in feet every second, and of the latter force \(\frac{4}{\pi^2} \frac{n^2 r}{\ell^2}\) (see note), \(n\) representing 3-1416, or the semi-circumference of a circle whose radius is 1, \(t\) being the number of seconds in one revolution, and \(r\) the radius = \(\text{MP}\).

\[
\therefore \text{NM} : r :: 32-17 : \frac{4}{\pi^2} \frac{n^2 r}{\ell^2},
\]

consequently

\[
32-17r + \frac{4}{\pi^2} \frac{n^2 r}{\ell^2} = 32-17 \times \frac{\ell^2}{4n^2} = 8-04 \frac{\ell^2}{n^2} = \text{NM}.
\]

The line \(\text{NM}\) thus determined is called the sub-normal to the curve at the point \(\text{P}\), and when the angular velocity of rotation is constant then the sub-normal is also constant in length, no matter in what part of the curve the point \(\text{P}\) is situated. This property belongs exclusively to the parabola. Hence the surface of a fluid rotating on an axis perpendicular to the horizon is a paraboloid.

To determine then the length of \(\text{NM}\) for different times of rotation—

\[
\text{Let } t = 1 \text{ second then } \text{NM} = 8-04 \frac{\ell^2}{n^3} = 0-814 \text{ feet.}
\]

\[
t = 2 \quad " \quad " \quad = 3-258 \quad "
\]

\[
t = 4 \quad " \quad " \quad = 13-037 \quad "
\]

Now that part of a paraboloid where a ray of light parallel to the axis will be reflected along a line forming a right angle to the axis must itself be inclined at an angle of 45°, consequently such reflected ray will, when it meets the axis, have traversed a distance equal to the length of the sub-normal, therefore at that part of the curve the two forces, namely gravity and centrifugal force, have the same measure, for they are represented in magnitude and direction by different sides of the same square.

Moreover this particular ray is the only one which will be reflected in a horizontal direction along the parameter of the paraboloid until it meets the axis in the focus of the curve. And since the distance \(\text{FV}\) equals the half \(\text{FP}'\) it also equals half \(\text{NM}\), by which we can obtain the focal length of the telescope for any velocity.

Within the range of our acquaintance with nature we have one remarkable and brilliant metal which
at ordinary temperatures exists in the liquid state, and we possess in mercury,
and possibly its amalgams, a surface of imperishable lustre; and, when its
equilibrium is established, then its perfection of surface may be safely taken to
be such as no human skill could produce upon other metals, for no magnifying
power, even that of the most powerful microscope, would be able to exhibit its
surface by its irregularities.

In telescopes of this description it is required: first, to construct a circular
axis and concentric cup; second, to fix it parallel to gravitation; third, to
give it an equable angular velocity. In the model before us will be seen the
degree of approximation attained to these requirements. It consists of an
upright steel axis about four inches long, the bottom of which rests on a fixed
conical pivot, while the upper part (which has been ground circular) is kept in
one position by a collar also ground circular. This collar admits of lateral
adjustment by screws, which should work on the differential principle. On
the top of the axis is fixed a flat disc or cup of beeswax which admits of
being easily turned true on the spindle itself, and surrounding this disc is a fly
wheel. In working this telescope it is first placed on a fixed base, and then
levelled by placing a spirit level across the cup, turning the cup round and
adjusting the screws till the bubble remains fixed. The axis is then truly
perpendicular, and sufficient mercury is then poured into the cup and rotation
communicated to it by any suitable power, in this instance a small electromag-
netic engine, the velocity of which is regulated by a conical pendulum.

We are now enabled to examine the printing placed on the ceiling of this
room by magnifying its image, which is formed in the focus, by looking down
into the mirror through the eye-piece; although the mirror is rather small for
this method of view, as the observer's head cuts off those rays which descend
nearest to the perpendicular, and which should consequently give the most
distinct definition, the rays moreover are not strictly parallel as they would be
if we were viewing a heavenly body, still we are enabled to judge of its
capabilities by the definition it gives of these letters. When such an
instrument is used for astronomical purposes the observations of course require
to be made an object at, or within a few degrees from the zenith, these are
always to be preferred for distinctness, on account of the rays traversing the
shortest section of the atmosphere, the sweep of the telescope in Right
Ascension being made by the earth's rotation.

It may be thought that we are debarred from obtaining a view of any part
of the visible heavens at any given time by the use of a horizontal speculum,
but such is not the case, for if the rays of light from any celestial body be first
received on a large plane mirror at such an angle of incidence that the
reflected rays shall descend vertically, such reflected rays will preserve their
parallelism, and the paraboloid will collect and reflect them upwards to the
eye-piece through an aperture left in the plane reflector. This is perforated to allow of a small telescope or finder to be used, or the finder can be placed at the side of the mirror as in Fig. 4. Let both plane mirror and finder have a vertical motion on a horizontal axis common to both, then since “the angle between the first and last direction of a ray of light suffering two reflections in the same plane, is twice the angle of the reflecting surfaces to each other,” and because the first direction of the ray is the same as the finder, and the last direction is towards the zenith, it follows that the angular motion of the finder must be twice that of the plane reflector; this is easily accomplished, and in such a manner that by merely turning the finder on to an object the reflector shall move through its proper angle.

Let AA (Fig. 4) represent a platform fixed above the speculum, H is a rod working an endless screw which turns a horizontal raked wheel, B, rotating on rollers running in grooves between the platform and the wheel. This wheel carries the pillars, II, consequently the mirror, C, and the finder, D, move in azimuth with equal velocities. The mirror is firmly braced on to the tube, TT, which carries with it the wheel, E, and E turns another broad wheel, F, which turns with the same speed as E, for that part of it which receives motion from E is equal to E. The other part of F has such a diameter as will give a motion to the wheel, G, of double the velocity of E. The ratios of the diameters of these wheels are E = 6, small part of F = 6, large part of F = 8, and small wheel G = 4. The dotted line represents a strong rod or axis, which also goes through the tube T. To this axis the wheel, G, and the finder, D, are firmly keyed. The finder is attached to, and moved in altitude by another raked wheel, also turned by an endless screw, K; then, whatever angular motion in altitude is imparted to the finder, the mirror shall receive one-half thereof. The eye piece is fixed near E, and is supported by connection with the pillars so as to be independent of any vertical motion of the mirror.

Such an arrangement gives the same degree of illumination as is given by the Newtonian telescope, there are two reflections, with this difference, that the light from the object is first received on the plane mirror instead of on
the concave one, and thus by simply turning the plane reflector on its axis we are saved the cumbrous alternative of moving the whole tubular length of the telescope in order that it may point to the object to be observed. In large instruments this must be a very important desideratum. Let us suppose a telescope twenty feet in diameter: ordinarily this would require tubing at least 120 feet in length, and provision would be required for its sweeping through 300 feet of motion; whereas with the horizontal speculum, a circular building thirty feet in diameter and about sixty feet high would furnish ample space, and also allow the observer, without changing his position, to work entirely under shelter.

In such an instrument the friction is reduced to a minimum by perfecting the bearing of a single axis, consequently little power is required for continuing its rotation.

I may remark that I have used, with good effect, the regular flow of water through a small turbine, in order to impart to the speculum an equal angular velocity. By merely altering the velocity we are enabled to shorten or lengthen the telescope, and in a few seconds the mercury attains its equilibrium, and not only the parts near the vertex are parabolic, but those also which extend to the parameter, and to any distance we like to go above, leaving out of consideration a very slight deviation caused by the earth's sphericity, which would impart a slight tendency to the hyperbolic curve, but which, even in immense instruments, would be so minute as to be within the power of correction by the eye-piece of the telescope.

It also follows that the focus can be observed by looking upwards, if the vertex of the curve be removed, and those parts only used which are above its parameter.

As it is of immense importance that we should be able to concentrate a large beam of light for examination of the distant nebulae, and especially for spectroscopic investigations, it is not improbable that the use of such an instrument, constructed on a large scale, would extend our knowledge of the natural heavens, for notwithstanding all the discoveries made in the great cosmic problems of creation, still, that we may be enabled to travel further into what is as yet the dark profound, and to gaze with bodily eye on what now form the manifold mysteries of the universe, must be the ardent wish of every lover of science.

NOTE.—That the above expressions are the dynamical measures of gravity and centrifugal force is thus shown:—

In circular motion the centripetal and centrifugal forces are everywhere equal. Let the arc AB be described in one second; draw BE perpendicular to AS; then in one second the body originally at A will have fallen from its wanted straight path, AM, a distance = AE towards the attractive force at
S; and because a uniformly accelerating force is measured by twice the space described from rest in one second, and it is found by experiment that the force of gravity on the earth's surface causes a body to fall from rest a distance of 16.1 feet in the first second of time, consequently the force of terrestrial gravity \( g = 32.2 \) feet, that is, this force continuously soliciting a falling body, will accelerate its velocity 32.2 feet every second; therefore \( 2AE \) expresses the intensity of gravity acting on \( A \). Join \( BA \); then since the arc \( AB \) differs insensibly from its chord (for the time of describing it may be made as small as we please) we may regard \( ABA' \) as a right angled plane triangle since the angle \( B \) is in a semicircle, therefore \( AE : AB :: AB : AA' \).

\[
\therefore \frac{AE}{AA'} = \frac{AB^2}{2AS} \times 2AE = \frac{AB^2}{AS} = \frac{v^2}{r}.
\]

Now \( 2AE \) represents the accelerating force at \( S \), or taken in an opposite direction, it represents the centrifugal force \( f \), and \( AB \) represents the velocity \( v \) in the curve; consequently the centrifugal force \( f = \frac{v^2}{r} \), where \( r \) = radius.

If, as is usual, \( n \) be made to stand for the number 3.14159, etc., the whole circumference of the circle will be \( 2\pi r \); therefore calling the whole time of describing the circumference—that is the periodic time, \( t \)—then the uniform velocity \( v \) being equal to the whole space divided by the whole time we have—

\[
v = \frac{2\pi r}{t}, f = \frac{4n^2 r}{t^2},
\]

for if \( v = \frac{2\pi r}{t} \) then \( \frac{v^2}{r} = \frac{2\pi r}{t} \times \frac{2\pi r}{t} = \frac{4\pi^2 r}{t^2} = \frac{4n^2 \pi^2 r}{t^2} \).

Deviation from the parabolic figure arising from the earth's sphericity only amounts to \( \frac{1}{871200} \) of an inch at the circumference of a speculum four feet in diameter.

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ART. XII.—Description of a Reflecting Telescope made in Wellington by W. F. Parsons. Communicated by James Hector, M.D., F.R.S.

[Read before the Wellington Philosophical Society, 23rd October, 1872.]

The instrument which I exhibit is a Newtonian model, with a silvered-glass speculum, and with the exception of the eye-pieces has been wholly made in Wellington by following the directions given in a paper by Mr. W. Purkiss,