COLLISION BALLS AND HARMONIC IMPACT.

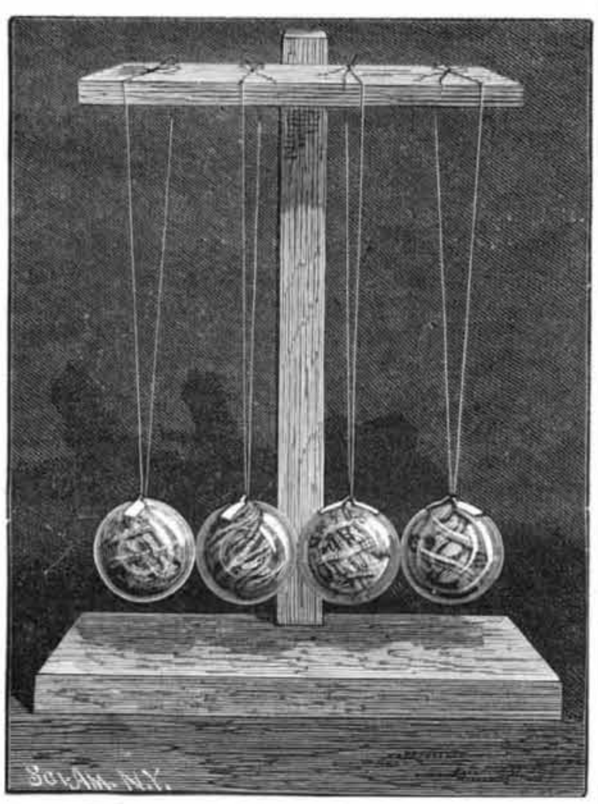
BY T. O'CONOR SLOANE, PH.D.

The laws of the impact of elastic bodies are very nicely illustrated by collision balls. As bought in the stores, this piece of apparatus is quite expensive. In the cheaper grades, the spheres are made of lignum vitae, which are too light and not sufficiently elastic. The higher priced ones are made with ivory spheres, and these naturally are better. But either kind is unsatisfactory. The first quality required is a high coëfficient of restitution of impact, or, as it may be more concisely expressed, a high degree of elasticity of impact. A body may be very elastic in one way, that is to say, it may recover its original figure after distortion perfectly, yet may not recover it quickly enough to possess the desired property. The next quality required is high specific gravity. Wood is so light that the resistance of the air affects it. The best substance for these balls, all things considered, is glass. Glass marbles are sold in the wholesale toy stores, of various sizes up to two inches in diameter. Six of these are enough for all purposes. They can be purchased at so low a price as to bring the cost of the apparatus down to a nominal amount. It is well to have one small one, half or three-quarters the diameter of the others. They have first to be prepared for suspension.

A hole may be readily drilled in each one by using a hard drill kept moist with camphor dissolved in spirits of turpentine. In this aperture a double suspension string may be secured by a wooden peg or by cement, finished even with the surface of the ball. As this is troublesome to do without a lathe, strips of leather may be pasted across the tops of the spheres. A portion of the center of each strip should be cut narrower than the rest, and a needle, bit of wire, or broom straw placed under and across this portion in pasting. Before the paste dries this must be withdrawn, leaving an opening for the string to go through. For paste, gum tragacanth, softened in water to the consistency of butter, must be used. It is spread over the leather, and the strip is put in place. At first it does not adhere to any extent, but as it dries it holds with extraordinary tenacity. Strong linen thread answers for suspending cords.

A simple support, 12 or 16 inches high, made of three pieces of wood is provided. Its construction is shown in the cut. On this the spheres are suspended by double threads, tied into loops. The tying must be such as to give the same length to all, and bring the balls into tangency in the same horizontal line. The object of the double suspension is to restrict the oscillations of all the balls to a single plane. Four or six marbles may be thus suspended.

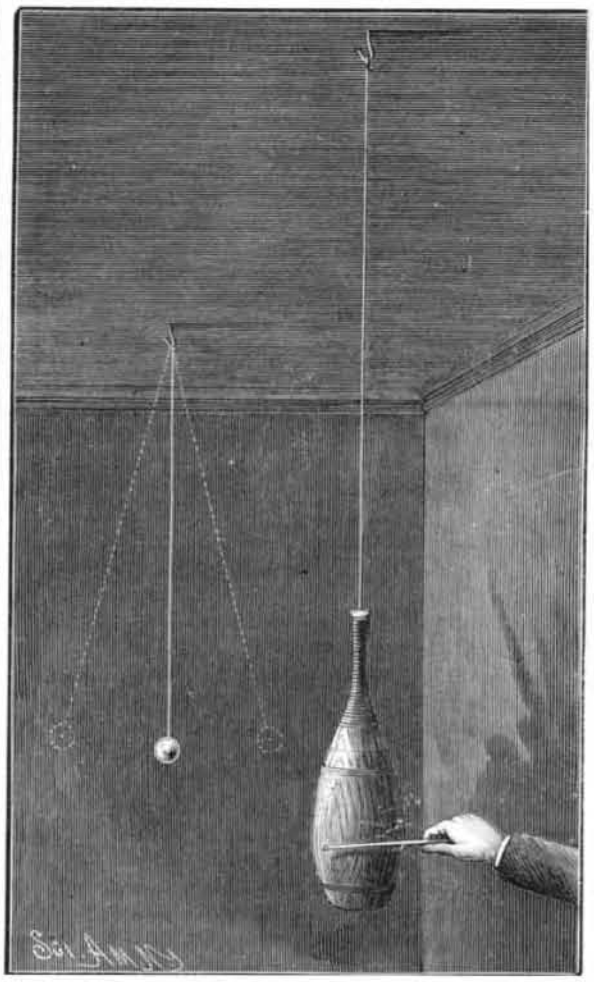
An end ball is swung aside, keeping it carefully in its plane and at the full stretch of its cord, and is released. It swings down and strikes its neighbor, comes to rest, and simultaneously the most distant one starts off, and, performing a half oscillation, returns, comes to rest, and the first one starts off in like manner. In this way the motion is kept up for some time, gradually degenerating into a swinging



COLLISION BALLS.

motion of all together. It can be done with two balls or more, and has a very good effect. With three balls on the frame, two may be swung aside and released. In this case, the center ball keeps swinging to and fro, accompanied first by one and then by the other of the end ones. A shock from a hard body is transmitted instantaneously through almost any number. A light blow from the back of a penknife causes the furthest ball to start away as if by magic. The lighter sphere falling produces a slighter effect in proportion to its weight. With two spheres, upward of a hundred impacts may occur before they come to rest.

It is essential that they shall be hung so as to be in full contact, yet not so as to press against each



HARMONIC IMPACT.

other. If this condition is departed from, their movements will be unsatisfactory.

The *rationale* of their action is that the impact slightly flattens each sphere, which, expanding, communicates the shock to its neighbor. The most impressive feature is the rapidity of the transmission of the shock and the evident conservation of energy that obtains. In some motions, it seems as if the balls were animated with life.

The production of motion from slight impacts repeated at proper intervals is shown in a simple experiment illustrated in the other cut. A heavy object, such as an Indian club, is hung at the end of a line about six or eight feet long. At a distance from it a weight is suspended, and the length of its string so adjusted that it swings in as perfect synchronism as possible with the club or heavier weight. The latter is now brought to rest, and the other weight is made to swing. Using it as a timer, light blows are given to the club, as near its central zone as may be. They are timed so as to strike it as the swinging weight reaches one end or the other of its course. At first no effect is visible, but on keeping up the impacts, striking with exactness, once for each double swing of the timing pendulum, the heavy club gradually begins to oscillate, and by perseverance may be made to swing over a large arc. The force of so many slight blows is stored up in its motion. Instead of striking it, the force of the breath may be used, a series of accurately timed puffs being discharged against it. A very heavy body may thus be set in motion.

This was the principle of some constructions of the battering ram. Very remarkable instances of the effect of such synchronous impacts have occurred in factories. The motion of an engine running at a particular rate has sometimes caused a series of shocks corresponding so closely with the periods of oscillation of the building as to threaten its destruction. In some cases a bucket of water could not stand on the floor without losing its contents. On running the engine faster or slower, these troubles have disappeared. In carrying a vessel full of water, care must be taken not to let the swing of the body correspond with the period of oscillation of the water contained. If it does, it will infallibly splash over the sides.

Impact of non-elastic bodies is attended with great loss of energy and corresponding development of heat. Recurring to the first experiment, balls of lead or little bags of sand may be substituted for the glass balls. In this case, after impact all the objects will swing together with greatly reduced energy. The impact develops heat, which is of course so slight as to be unappreciable. In the second experiment where impact is used, the body striking and the one struck should both be as elastic as possible. If the impact in either experiment be produced by the tip of the finger, no push being given, its action will amount to very little. The slightest blow with a hard object will have an effect much greater than a comparatively hard blow (not push) with the finger.

POLARIZED LIGHT.—NORREMBERG DOUBLER AND THE STUDY OF THIN FILMS.

BY GEO. M. HOPKINS.

III.

One of the simplest and best instruments for a certain class of investigations in polarized light is the Norremberg doubler, named after its inventor, and shown in a very simple form in the annexed engraving.

To one edge of a wooden base, 6 inches square and three-fourths of an inch thick, is secured a vertical standard, 1 inch square and about 15 inches high, and to the top of the standard is attached an arm extending over the center of the base, and apertured to receive the short tube containing the analyzing prism or bundle of glass plates. The tube may be made of paper, hard wood, or metal, and it should be fitted with a shoulder, so that it will turn readily in the aperture of the arm. To the standard below the arm is fitted a stage formed of a thin piece of wood centrally apertured and blackened.

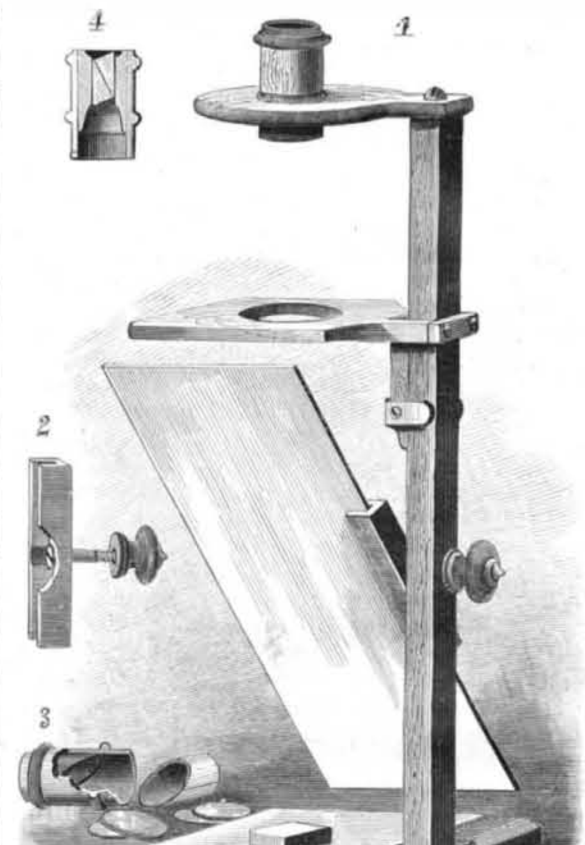
The stage is notched to receive the standard, and is attached to a short vertical bar 1 inch wide. A clip of wood extending across the back of the bar, and two small clips secured to the sides of the short vertical bar, bear with sufficient friction on the standard to hold the stage in any desired position.

About 6 inches above the base a grooved wooden strip is pivoted to the stardard, by means of a common wooden screw, passing loosely through the grooved strip and tightly through the standard. A wooden knob is turned on the end of the screw, and serves as a nut to bind the grooved strip in any desired position. The strip, screw, and knob are shown in detail in Fig. 2.

Into the groove of the strip is wedged or cemented a plate of glass, 4 by 9 inches. A fine piece of ordinary window glass will answer, but plate glass is preferable.

Upon the base is laid a square of ordinary looking-glass, or, better, a piece of plate mirror.

The tube shown in detail partly in section in Fig. 3 is provided with an inner tube of pasteboard or wood, divided obliquely at an angle of 35° 25' with the axis of the tube, and upon the oblique end of one half of the tube are placed twelve or fifteen well cleaned elliptical microscope cover glasses, which are held in place by the other half of the divided tube. This bundle of glass plates, if of good quality and well cleaned, forms a very good analyzer; but instead of this, if it can



SIMPLE NORREMBERG DOUBLER.

be afforded, a small Nicol prism should be secured and mounted in a centrally apertured cork, the latter being inserted in the analyzer tube, as shown in Fig. 4.

The object to be examined may be laid either on the stage or on the mirror below. If viewed on the stage, the usual effects will be observed; but if laid on the mirror, it is traversed twice by the light, once by the incident beam and once by the reflected beam. This is particularly noticeable in thin films of mica and selenite, and it serves as an excellent means for selecting eighth and quarter wave plates, which are useful in the study of circular and elliptical polarization.

As stated in a former article, the writer intends to deal sparingly with the theoretical part of the subject, that having been treated extensively in many physical works and in books especially devoted to light and optics. "Ganot's Physics" is prominent among works of its class, and "Light," by Lewis Wright, and "Polarization of Light," by William Spottiswoode, are excellent books bearing directly on the subject. The writer knows of no better means of securing a good knowledge of polarized light than by reading these three books.*

Returning to the matter of the thin films: It is quite difficult to produce a perfectly uniform thin film of selenite, owing to the brittleness of the material. For this reason, mica is generally used, as it possesses considerable flexibility and toughness. The common method of cleaving off thin films of mica is to split off a moderately thin plate and then separate the laminæ at one of the corners by bending it between the thumb and fingers. A medium sized sewing needle secured point outward in a slender handle is probably the best instrument for teasing the laminæ apart; but after the separation begins, the thin end of the ivory handle of an ink eraser seems to serve the purpose exceedingly well.

A score or so of plates are split, and examined one by one in the Norremberg doubler, by laying them on the mirror and turning them in their own planes, while the polarizer and analyzer are parallel. Should the plates exhibit any unevenness under the test, they should be at once rejected. Such as exhibit an even tint should be preserved carefully, and examined further to determine which, if any, possess the required qualities. Not every piece of mica will split evenly, therefore it may be necessary to make several trials before success is attained.

Should the film, when placed on the stage, exhibit a dull plum color, slightly inclined toward red, when the polarizer and analyzer are parallel, it produces a difference of phase of half a wave length, and is called a half wave film. As a matter of course, if two films of like thickness, superposed and arranged with their axes in the same direction, produce the same color under the same circumstances, they are one-fourth wave films; and if a pair of films exhibit the same color when similarly arranged on the mirror of the doubler, they may be regarded as eighth wave films, as the polarized beam passes twice through the film to produce the same tint. These films should be carefully mounted between glass plates, either dry or in benzole balsam, the latter being preferable.

The practical application of the eighth and quarter wave films will be treated in a future paper. Beautiful and instructive designs made from thin films are described and illustrated in Wright's "Light," to which reference has been made.

* These books may be had at this office at publishers' prices.—ED.

WINDING ENGINE FOR AUSTRALIA.

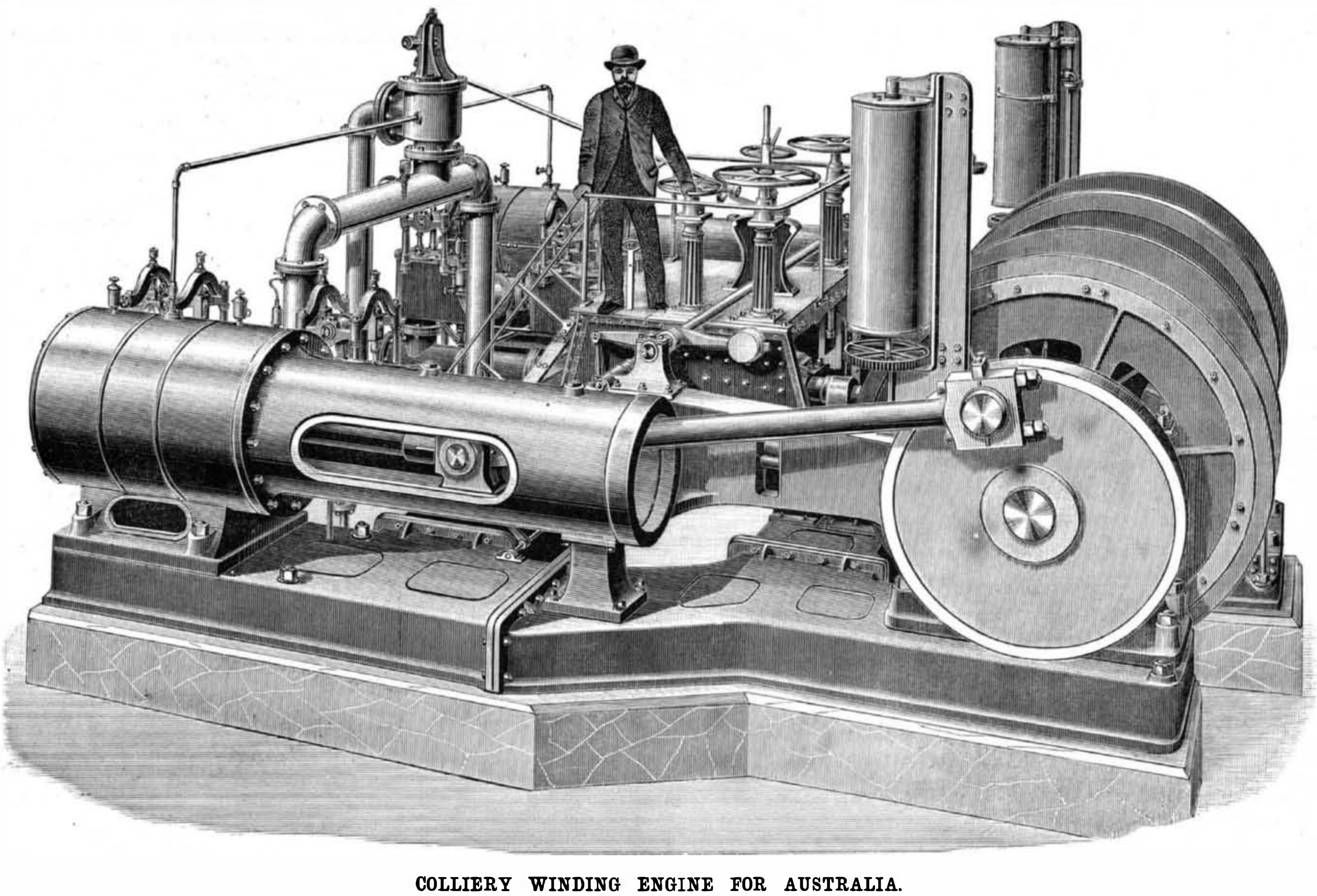
The winding engine illustrated by the accompanying engraving, which we take from *The Engineer*, was made by Messrs. Tangye, of Birmingham, England, under the instructions of Mr. J. D. Baldry, M.I.C.E., for use in the extensive coal mines of the Australian Agricultural Company, of New South Wales. This design, which, in some respects, is a departure from general practice, has proved satisfactory in all respects, and has met with special approval from mining engineers in the colonies. The cylinders are 32 inches in diameter by 48 inches stroke, and are steam-jacketed, with separate steam pipes and valves for supplying the jackets direct from the main supply pipe. The steam and exhaust valves are of the Cornish type, double beat equilibrium, two separate nozzle boxes being fitted to each cylinder containing the valves.

The crank shaft is of Siemens-Martin steel, 10½ inches in diameter at the journals. The bearings are in three parts, of gun metal, with wedges and screws for adjustment, and arranged so that they can be removed without taking out the shaft.

The hauling drums are 6 feet in diameter by 3 feet wide, are loose on the shaft, and are driven by steel clutches. Each drum is provided with a brake, fitted with oak blocks. Between the engines is a raised platform, on which are placed the clutches, brakes, wheels, reversing lever, steam valve handle, and rods for working the condenser steam cocks. The engines, platform, etc., are mounted on a strong cast-iron bed plate.

As these engines are to haul about 2,000 yards, they are fitted with an arrangement for accurately indicating the position of the tubs at any point in their journey. This consists of a vertical drum rotated by gearing, and having traced upon it a spiral line, along which the positions of the various stations are marked. A pointer moving on a screwed shaft, driven by worm gearing from the main drum, traverses the spiral, and so indicates the position of the truck.

The speed of hauling is 9 miles per hour, and about eighty skips, of 10 cwt. each, make up a load.



COLLIERY WINDING ENGINE FOR AUSTRALIA.

THERMOMETER WITH ELECTRIC ALARM.

GERBOZ'S ALARM THERMOMETER.

The thermometer figured herewith is designed for giving indications as to the temperature of silos, grain depositories, piles of coal, or certain fabrics that are apt to burst into flame spontaneously and set fire to factories or ships.

The thermometer used is a metal one, of the Bourdon type, inclosed in a strong cast iron box, provided with a cover of the same nature. This latter is omitted in the figure, so that the internal arrangement may be seen. This box is everywhere perforated, so that the thermometer may be in contact with the surrounding air. The apertures, however, are small enough to prevent the entrance of particles of coal or fragments of seeds, etc.

The apparatus, when placed in a coal bunker or a silo, is connected with the exterior by means of conductors that traverse the surrounding substance, and that serve to indicate, at every moment, that the temperature has or has not reached a dangerous height. As soon as the needle of the thermometer strikes an index, placed at the degree of temperature that it is important to know (50°, for example, showing that there is danger of fire), a bell rings.

We shall now give a few details of construction: As the rotary axis of the needle and that of the index are on the same line, contact between these two pieces takes place at the same point, whatever be the respective angular position of these two parts. Instead of being a simple rod, making one piece with the maneuvering button, the index is composed of a barrel that forms one piece with the button, and upon which is mounted (1) the index needle properly so called, (2) a spring for holding the index in a constant position with respect to the barrel, and (3) a toothed pinion. This latter gears with a cog wheel upon the same axis with the polarized armature of an electro-