RATIONAL RECREATIONS.

VOLUME THE SECOND.

CONTAINING

EXPERIMENTS

IN

OPTICS, CHROMATICS,

AND

ACOUSTICS.

RATIONAL RECREATIONS,

In which the PRINCIPLES of

NUMBERS

AND

NATURAL PHILOSOPHY

Are clearly and copiously elucidated,

BY A SERIES OF

EASY, ENTERTAINING, INTERESTING

EXPERIMENTS.

Among which are

All those commonly performed with the CARDS.

By W. HOOPER, M. D.

VOL. II.

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DESCRIPTION of the PLATES.

PLATE I. p. 8.

FIG. 1. Shows the manner in which the rays of light converge and diverge.

Fig. 2. Different objects ſeen under the ſame optic angle.

Fig. 3. The refraction of a ray of light, AB, in paſſing through different mediums.

Fig. 4. The different ſorts of lenſes.

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Fig. 3. Shows the ſtructure of a reflecting teleſcope. GH is a large concave metalline mirror,

perforated at *r*, by which the image of an object, entering at the end of the tube DE, is reflected to the small mirror I, placed on a stand, and by that to the glasses B and A, which convey it to the eye in an erect position.

Fig. 4. The construction of a double microscope. AB the object-glass, and CD the eye-glass: *g m b* the object, and GH the image, which appears inverted and greatly magnified.

PLATE III. p. 33.

Fig. 1, is a vessel with water, by the refraction of the light through which three pieces of money E, F, G, are seen at the point where they were invisible before the water was poured into the vessel.

Fig. 2. Three small pieces of paper A, B, C, being stuck against the wall, the image of one of them will always fall on the optic nerve at D, and therefore be invisible.

Fig. 3. The portable camera obscura. E is a plate of glass placed in the frame ABCD, to which the image of the objects that enter the tube O, are reflected by the mirror N. The four legs and the pieces that compose the case H, have hinges, by which they fold up.

Fig. 4. The magic lantern. ABCD is a tin box, in one end of which is a concave mirror G; at the opposite end is a convex lens L, and before it a tin tube O, that has an opening MN, through which are passed the glasses that have the objects

8 painted

painted on them. In the tube O is placed another, that is moveable, and that contains two lenſes P and Q, by which the objects on the glaſſes are thrown on the wall: K is a lamp, and E, F the funnel by which the ſmoke comes out, and its cover that keeps in the light.

PLATE IV. p. 50.

Fig. 1, and 2, are two plates of glaſs, to paſs through the groove in the magic lantern at the ſame time, and by which the appearance of a tempeſt is to be exhibited.

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Fig. 1. Repreſentation of an object reflected by a plain mirror. A the object, GI the mirrorr, DF the image.

Fig. 2. G I is a convex mirror, A C the object, and DF the image.

Fig. 3. GI a concave mirror, AC the object, DF the image, that appears behind the mirror and erect.

Fig. 4. GI a concave mirror, AC an object at a greater distance, than in the last figure; DF the image before the mirror, inverted and diminished.

PLATE VI. p. 70.

Fig. 1. The box for the boundless gallery: EF two pasteboards cut through, and painted on both sides; D a pasteboard painted on one side only, and placed before a mirror at that end of the box; C is the hole by which the objects are viewed.

Fig. 2, and 3. The painted pasteboards to place in the box, Fig. 1.

Fig. 4. The box for the four magical mirrors. ABCD the body of the box, against whose four insides the mirrors are placed. AEBNLI a frame of glass consisting of four inclined plates, and one at top that is horizontal; by the latter the images placed on the bottom of the box are seen reflected by the mirrors.

Fig. 5. A plan for disposing the objects in the box, Fig. 4.

PLATE VII. p. 79.

Fig. 1. The enchanted palace. Against the six pillars mirrors are fixed, that meet in the center, and between each triangular division objects are placed, that are reflected by the mirrors. ABCDEF is the plan of the base of the palace.

Fig. 2, is a ſquare on which a regular figure is drawn, that when transferred to the correſponding diviſions of Fig. 3, appears deformed, but when ſeen in a mirror placed at FG, from a point over B, appears exactly the ſame as on Fig. 2.

Fig. 4. The magical dial. In the drawer H is placed the dial Fig. 5, whoſe index is a touched needle that is moved by a magnetic bar under the dial-plate. At I another dial, Fig. 6, is placed, whoſe index is likewiſe a touched needle, and is regulated by that on Fig. 5. At M is an inclined mirror, that reflecting the dial placed at I, makes it viſible at an opening in that center of the dial at the top of Fig. 4.

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Fig. 1. The box of divination A B C D, in which are placed the tablets 1, 2, 3, 4, that each contains a magnet placed in a different poſition.

Fig. 2, the table, under which is a braſs rod that has four pivots, to which are fixed the four paſteboard circles P, Q, R, S, Fig. 3. MN is an inclined mirror placed in a drawer under the table.

Fig. 4, is the top of a box, that has three holes, and over them are placed three perſpectives like Fig. 6. Each of theſe perſpectives is fixed on a hollow pedeſtal, and contains a mirror E, by which the objects on the circle Fig. 7, that is put at the bottom of the box, are ſeen at D. There is a magnetic bar concealed in the table, on which the box is placed, that moves the circle Fig. 7, by the needle in the middle of it.

Fig. 5, is a column placed on the middle of the box, and in which the spectators seem to see the objects shown by the perspectives.

PLATE IX. p. 112.

Fig. 2. The box for the animated optic balls. IM the inclined plane, down which the ball O runs, and through the groove P, to the hole at the end of the box. RF is the mirror that reflects the inclined plane and the paintings in the box to the glass at E, and which is represented by Fig. 1. T the inclined plane for a double reflection. Fig. 4, 5, and 6, the machinery that raises the ball to the top of the inclined plane.

Fig. 3. The painting on the inclined plane.

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Fig. 3. The enchanted mirrors. AD and CB the two mirrors placed cross the box in a diagonal. H and

H and L, two of the glaffes by which the fpectators fee each other.

Fig. 5. The machine for feeing an irregular figure in a multiplying glafs. A B the ftand with the glafs fixed to it; H the hole through which the image is feen. Fig. 6. the ruler for drawing the reflection on the board D E F G. Fig. 7, 8, and 9, projections of the glafs.

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Fig. 3. The plan for drawing the regular figure.

Fig. 4, 5, and 6. The appearances of a bottle of water before a concave mirror.

PLATE XII. p. 134.

Fig. 1. The perfpective mirror. H the concave mirror, IL the blacked pafteboard for regulating the view, C the aperture for viewing the objects placed beneath it, in the mirror.

Fig. 2. A and B two concave mirrors for firing combuftible bodies at a diftance. C and D their foci, in which the bodies are placed.

Fig.

Fig. 3. The machinery for the real apparition. C an inverted object placed under the hole in the partition AB, and which, by the reflection of the concave mirror, appears erect at D, on the outside of the partition.

PLATE XIII. p. 160.

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Fig. 5. The prismatic camera obscura. F *f* two rays of light that being refracted by the prisms A, B, C, and *a*, *b*, *c*, form the spectrum MN, which appears to be painted with all the original colours.

PLATE XIV. p. 166.

Fig. 1. A ray of light largely refracted into the spectrum PT, the divisions of whose colours correspond to the divisions of a chord for the notes of the octave.

Fig. 2, and 3. The machine for exhibiting colorific

lorific music. The shaded parts in Fig. 2, represent the colours. F is the screw on which it turns, G a wheel that is moved by the endless screw H.

Fig. 3, is the case that contains the cylinder. The eight shaded parts in the middle are the holes through which the colours on the cylinder are seen; O the handle that turns the endless screw.

PLATE XV. p. 173.

Fig. 1, 2, and 3. The plans for drawing an irregular figure that will appear regular when seen through a hole in the stand Fig. 4, placed in the proper position.

PLATE XVI. p. 178.

Fig. 1, 2, and 3. The plans for drawing an irregular figure, which when seen from two opposite points of view, presents two regular figures.

Fig. 4. A pasteboard in which lines are cut, and over them the paper Fig. 5, that contains the drawing is to be pasted.

PLATE XVII. p. 181.

Fig. 1, and 2. The apparatus for drawing an irregular figure on the base of a cone, that appears regular from the point H; FEG the cone; MN the position of a glass on which the regular figure is drawn, and that is projected on the cone by by the lamp Fig. 2, when placed in the room of the ſtand HI.

Fig. 3. The machine for drawing any object correctly. EAC the tube for viewing the object; BFDG the frame, ſhown more clearly in Fig. 4, by which the parts of the object are transferred to ſimilar diviſions on a paper.

Fig. 5. The box for illuminated proſpects. EFGH the back of the box in which the prints are placed, and behind them lamps or candles.

PLATE XVIII. p. 222.

Fig. 1, ſhows the alternate vibrations of a chord.

Fig. 2. A chord ſo divided as to ſound the ſeven concords.

Fig. 3. The apparatus for the ventoſal ſymphony. A the vane that gives motion to the machine, ; C, D, G, H, I, M, wheels and pinions that ſerve to move the barrel NO, in which are a number of ſtops, that ſtrike a ſet of bells.

Fig. 4. The whiſpering gallery. A the point from whence the ſound proceeds, and is reverberated by the points DEFG, to C, where it is plainly heard.

Fig. 5. The converſive ſtatue. AB and GH are two concave mirrors; C and I their centers; EF a partition that has a hole, through which a ſound iſſuing at I, is diſtinctly heard at C.

PLATE XIX. p. 240.

Fig. 1, ſhows the mechaniſm of the great organ. O, O, are the handles that puſh down the bellows TT:

T T: *l*, *l*, are the handles that turn the rollers R, R, that by means of the arms *e*, *f*, pull out the sliders *f*, *g*, and give liberty to the pipes placed over any row of the holes to sound; C, D, E, &c. are the keys, which being put down open the valves V, that admit the air to the pipes: HIKK is a wind-chest, that receives the air by the port-vent 4. X is a flute-pipe of wood; Y a trumpet-pipe of metal; Z a flute-pipe of metal.

Fig. 2, shows the construction of a valve, with the wire that opens it and the spring that shuts it.

Fig. 3. The inside of a flute-pipe. A B the foot; BD the body; EF the partition; BC the mouth.

Fig. 4. A reed pipe; AB the foot; CD the shallot or reed; KL a plate of copper fitted into the mould at I, but being loose at its extremity K, the air makes it shake against the reed.

RATIONAL

RATIONAL RECREATIONS.

OPTICS.

THE ſcience of optics explains the nature of viſion, by inveſtigating the cauſes of the various phenomena that ariſe from the refraction and reflection of light. It is divided into Dioptrics, Catoptrics, and Chromatics *. The firſt treats of refraction; the ſecond, of reflection; and the laſt, of colours.

GENERAL DEFINITIONS.

1. When the rays of light that iſſue from any body, continually recede from

* Theſe terms are derived from the Greek; the firſt from the word *dioptra*, a perſpective glaſs; the ſecond from *katoptron*, a mirror; and the laſt from *chromata*, colours.

 each

each other, as the rays A B and A C (Plate I. Fig. 1.) they are ſaid to diverge.

2. When rays in their progreſs draw continually nearer to each other, as the rays B F and C F, (Plate I. Fig 1.) they are ſaid to converge.

3. That point in which converging rays all meet, is called their focus; as the point F, in the ſame figure.

4. An optic angle is the ſpace contained between two lines drawn from the extremities of any object to the eye. Thus A E B or C E D (Plate I. Fig. 2.) are the optic angles under which the objects A B and C D appear to the eye at E.

GENERAL APHORISMS.

1. The motion of light is not inſtantaneous but progreſſive *.

2. All rays of light naturally proceed in right lines.

3. No object can be ſeen diſtinctly at a leſs diſtance than about eight inches.

4. To produce diſtinct viſion, the rays of light muſt be parallel when they enter the eye.

5. Rays of light that come from a far diſtant object, are to be conſidered as parallel.

6. Wherever the rays that come from all the points of an object, meet again in

* It appears, by aſtronomical obſervations, that the rays of light are 8 minutes and 13 ſeconds in coming from the ſun to the earth, which are diſtant about 82 millions of miles; their progreſs, therefore, is at the rate of about ten millions of miles in a minute; yet great as that velocity is, the diſtance of the largeſt, that is, the neareſt of the fixed ſtars, being four hundred thouſand times greater than that of the ſun, the light muſt be more than ſix years in coming from them to us.

ſo many points, after they have been made to converge by refraction or reflection, they will there form an image of that object on any white body.

7. Every object ſeen by refraction or reflection, appears to be in that point from whence its rays are laſt refracted or reflected to the eye.

8. The apparent magnitude of any object is determined by the magnitude of its optic angle: therefore the objects A B and C D, (Plate I. Fig. 2.) which are ſeen under the ſame angle, will appear of equal magnitude.

Theſe, and every other aphoriſm in this treatiſe, are confirmed by all optical writers; and may be demonſtrated geometrically: but as we ſuppoſe our readers to have no other previous knowledge than that of common arithmetic, it would be ſuperfluous to inſert ſuch demonſtrations here.

DIOP-

DIOPTRICS.

DIOPTRICS, as we have ſaid, explains the ſeveral appearances that ariſe from the refraction of light.

DEFINITIONS.

1. When a ray of light paſſing out of one medium into another of a different denſity, is turned from that ſtrait line in which it would otherwiſe proceed, into one of a different direction, it is ſaid to be refracted. Thus the ray A B, (Plate I. Fig. 3.) by paſſing out of air into the glaſs G H, is turned from its natural courſe into that of C D.

2. Any ſpherical tranſparent glaſs, that converges or diverges the rays of light as they paſs through it, is called a lens.

3. Of lenſes there are five ſorts: 1. A plane or ſingle convex lens, which is plane on one ſide, and convex on the other, as A (Plate I. Fig. 4.) 2. A double convex lens, as B. 3. A plano-concave lens,

that is, plain on one ſide and concave on the other, as C. 4. A double concave, as D. And 5. A meniſcus, which is convex on one ſide and concave on the other, as E.

4. The point C, round which the ſpherical ſurface of a lens, as A Z (Plate I. Fig. 4.) is deſcribed, is called its center: the line X Y, drawn from that center perpendicular to its two ſurfaces, is the axis; and the point V, to which the axis is drawn, is the vertex of that lens.

5. When the rays of light that paſs through a ſingle or double convex lens are brought into their ſmalleſt compaſs, that point is the focus of the lens.

6. In optical inſtruments that lens which is next the object is called the object-glaſs; and that next the eye, the eye-glaſs.

7. The diſtance between the line A F (Plate I. Fig. 3.) and the perpendicular E B, is called the angle of incidence; and the diſtance between the line C D and the perpendicular B F, is called the angle of refraction.

APH-

APHORISMS.

1. A ray of light passing obliquely out of one medium into another that is denser, will be refracted toward the perpendicular, as the ray A B (Plate I. Fig. 3.) by passing out of air into glass is refracted into CD, toward the perpendicular B F. On the contrary, a ray passing out of a denser into a rarer medium, will be refracted from the perpendicular; as the ray B C, passing out of glass into air, is refracted into D I.

2. The angles of incidence, and refraction, when the lines that contain them are all equal, will have a determinate proportion to each other, in the same mediums: which between air and water will be as 4 to 3; between air and glass, as 3 to 2, nearly; and in other mediums in proportion to their densities.

3. When an object is viewed through a glass whose two surfaces are parallel, it will appear of its natural dimensions, its situation only being a small matter altered,

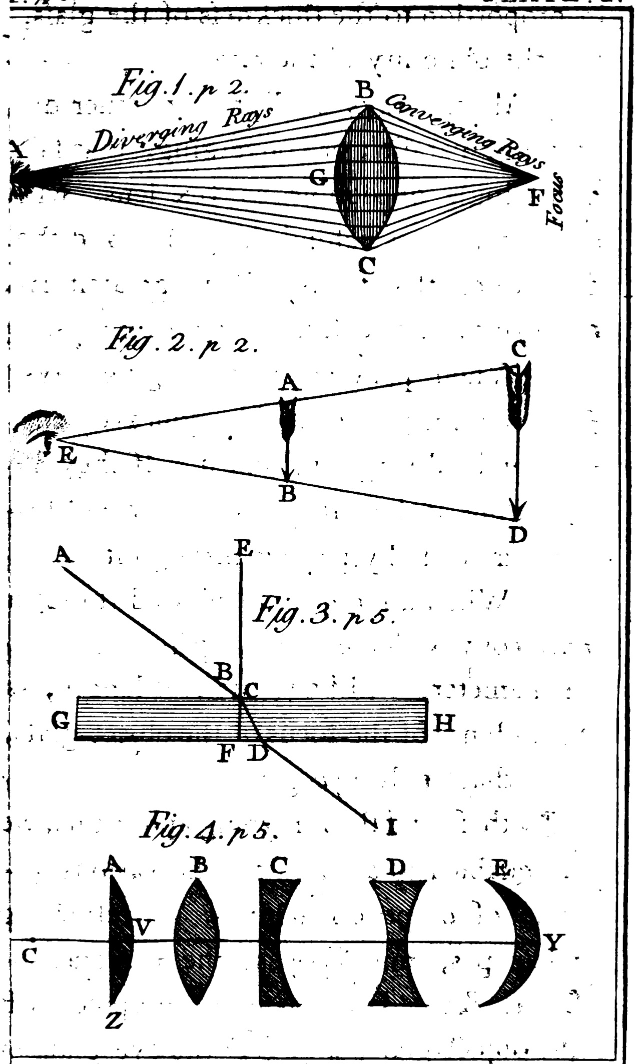
in proportion to the thickneſs of the glaſs, and the obliquity of the rays.

4. All the rays of light, whether diverging, parallel, or converging, that fall on a ſingle or double convex lens, will meet in a focus behind the glaſs: and the diſtance of that focus will be greateſt in diverging, and leaſt in converging rays.

5. When parallel or converging rays, fall on a ſingle or double concave lens, they will diverge behind it. If they be diverging at their incidence, they will become more ſo by paſſing through it.

6. When an object is viewed through two convex lenſes, its apparent length, or diameter, will be to its real length, as the diſtance of the focus of the object-glaſs, is to that of the eye-glaſs.

By theſe, and the foregoing aphoriſms, we are enabled to account for the various effects of dioptric machines, as refracting teleſcopes, microſcopes, the camera obſcura, &c. For example, ſuppoſe A B the object-glaſs, and C D the eye-glaſs of a te-



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a telescope, (Plate II. Fig. 1.) and let them be so placed that the focus of each may coincide in the point F. Suppose O I to be a far distant object, whose rays are therefore to be considered as parallel when they come to the glass, (aphorism 5. page 3.) the two rays OA, and I B, proceeding from the extremities of the object, and passing through the glass A B, will meet and intersect each other in its focus F, and pass on to the eye-glass C D. But F being also the focus of that glass, those rays, by passing it, will again become parallel, and therefore by (aphorism 4. p. 3.) produce distinct vision in the eye, placed at H.

Now suppose the distance between A B and F, that is, the focal length of the object-glass, to be 10 feet, or 120 inches, and the distance between F and C D, which is the focal length of the eye-glass, to be three inches, then by aphorism 6. p. 8. the apparent length or diameter of the object will be to its real length as 120 to 3,

or

the reflection, by which objects appear so distinct that an eye-glass of a much smaller focus can be used in them than in others. The magnifying power in this, as in other telescopes, is as the focal distance of the object-glass or mirror, to the focal distance of the eye-glass. But the latter being so much smaller in this telescope, the magnifying power will be so much greater. Therefore, if the focal distance of the eye-glass be one inch, and that of the object-mirror 40 inches, the diameter of the object will be magnified 40 times, and its surface 1600 times. A reflecting telescope of 4 feet will magnify more than a refractor of 50 feet.

Suppose, again, A B, (Plate II. Fig. 4.) to be the object-glass, and the C D the eye-glass of a double microscope. The object-glass must here be quite small and very convex, and consequently its focal distance *l f*, very short. The distance of the small object *g m h*, must be very little more

Fig. 1. p 9.

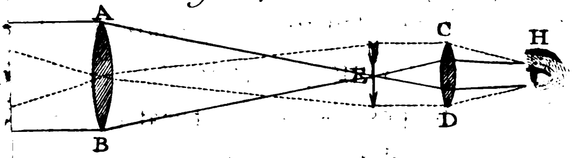


Fig. 2. p 10.

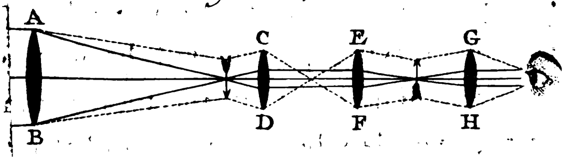


Fig. 3. p 11.

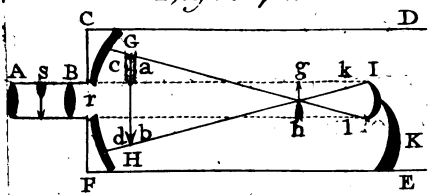
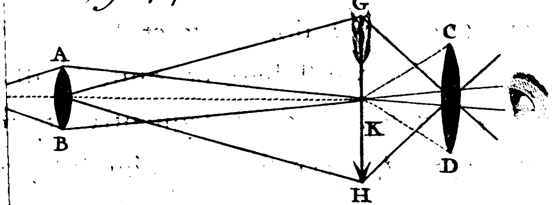


Fig. 4. p 12.



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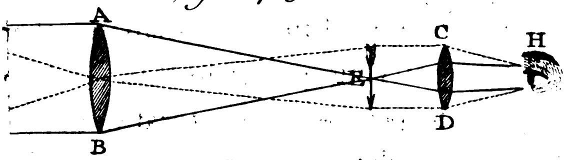

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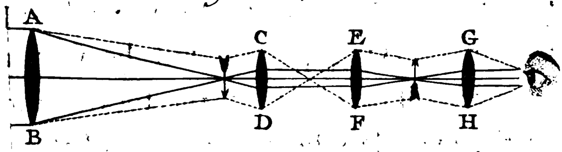

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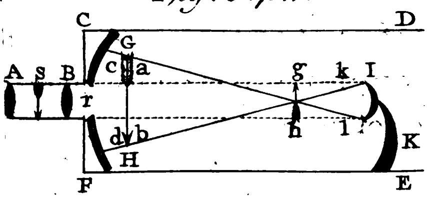
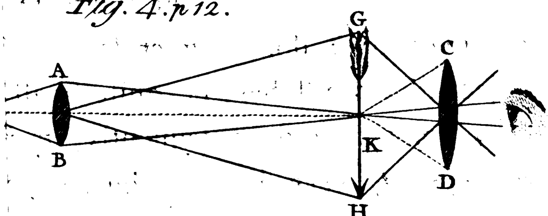


Fig. 4. p 12.



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more than that of *lf*, in order that its image G H, may be formed at a confiderable diftance, and confequently be much enlarged. Now this image will appear diftinct and confiderably magnified, and that on two accounts: firft, in proportion as the diftance K *l* is greater than *l m*; and fecondly, on account of the nearnefs of the eye to the image; for by aphorifm 3, page 3. no object can be feen diftinctly by the naked eye, at a lefs diftance than eight inches, therefore if by means of the eye-glafs C D, the object is made to appear diftinct at the diftance of one inch, it will feem eight times as large. Suppofing, therefore, the focal diftance of the eye-glafs C D, to be one inch, and the diftance K *l* to be to *l m*, as 10 to 1, then, on both thefe accounts, the length of the object will appear 8 times 10, or 80 times, and its furface 6400 times, larger than when feen by the naked eye.

RECREATION I.

Optical illusions.

ON the bottom of the veſſel ABCD, (Plate III. Fig. 1.) place three pieces of money, as a ſhilling, a half-crown, and crown; the firſt at E, the ſecond at F, and the laſt at G. Then place a perſon at H, where he can ſee no further into the veſſel than I: and tell him that by pouring water into the veſſel you will make him ſee three different pieces of money; biding him obſerve carefully whether any money goes in with the water *.

When the water comes up to K, the piece at E will become viſible; when it comes up to L, the pieces at E and F will appear; and when it riſes to M, all the three pieces will be viſible.

* You muſt either pour it in very gently, or contrive to fix the pieces, that they may not move out of their places by the motion of the water.

From

From what has been ſaid of the refraction of light, the cauſe of this phenomenon will be evident: for while the veſſel is empty, the ray HI will naturally proceed in a ſtraight line: but in proportion as it becomes immerſed in water, it will be neceſſarily refracted into the ſeveral directions NE, OF, PG, and conſequently the ſeveral pieces muſt become viſible.

RECREATION II.

Optical Augmentation.

TAKE a large drinking glaſs of a conical figure, that is, ſmall at bottom and wide at top; in which put a ſhilling, and fill the glaſs about half full with water: then place a plate on the top of it, and turn it quickly over, that the water may not get out. You will then ſee on the plate, a piece of the ſize of a half crown; and ſomewhat higher up, another piece of the ſize of a ſhilling.

This

This phenomenon arises from seeing the piece through the conical surface of the water at the side of the glass, and through the flat surface at the top of the water, at the same time: for the conical surface dilates the rays and makes the piece appear larger; but by the flat surface the rays are only refracted, by which the piece is seen higher up in the glass, but still of its natural size. That this is the cause will be further evident by filling the glass with water, for as the shilling cannot be then seen from the top, the large piece only will be visible.

After you have amused yourself with this remarkable phenomenon, you may give the glass to a servant, telling him to throw out the water, and take care of the two pieces of money; and if he have no suspicion of the deception, he will be not a little surprised to find one piece only.

RECREATION III.

Optical subtraction.

AGAINST the wainscot of a room fix three small pieces of paper, as A, B, C, (Pl. III. Fig. 2.) at the height of your eye; and placing yourself directly before them, shut your right eye and look at them with the left; when you will see only two of those papers, suppose A and B; but altering the position of your eye you will then see the third and one of the first, suppose A; and by altering your position a second time, you will see B and C; but never all three of them together.

The cause of this phenomenon is, that one of the three pencils of rays that come from these objects, falls constantly on the optic nerve at D; whereas to produce distinct vision it is necessary that the rays of light fall on some part of the retina E, F, G, H. We ſee by this experiment, one of the uſes of having two eyes; for he that has one only, can never ſee three objects placed in this poſition, nor all the parts of one object of the ſame extent, without altering the ſituation of his eye.

RECREATION IV.

Alternate illuſion.

WITH a convex lens of about an inch focus, look attentively at a ſilver ſeal, on which a cypher is engraved. It will at firſt appear cut in, as to the naked eye; but if you continue to obſerve it ſome time, without changing your ſituation, it will ſeem to be in relief, and the lights and ſhades will appear the ſame as they did before. If you regard it with the ſame attention ſtill longer, it will again appear to be engraved: and ſo on alternately.

If you look off the ſeal for a few moments, when you view it again, inſtead

ſtead of ſeeing it, as at firſt, engraved, it will appear in releif.

If, while you are turned toward the light, you ſuddenly incline the ſeal, while you continue to regard it, thoſe parts that ſeemed to be engraved will immediately appear in relief: and if, when you are regarding theſe ſeeming prominent parts, you turn yourſelf ſo that the light may fall on the right hand, you will ſee the ſhadows on the ſame ſide from whence the light comes, which will appear not a little extraordinary. In like manner the ſhadows will appear on the left, if the light fall on that ſide. If inſtead of a ſeal, you look at a piece of money, theſe alterations will not be viſible, in whatever ſituation you place yourſelf *.

* It has been ſuſpected that this illuſion ariſes from the ſituation of the light; and in fact I have obſerved, (ſays M. Guyot, from whom this article is taken) that when I have viewed it with a candle on the right, it has appeared engraved, but

RECREATION V.

The camera obſcura, or dark chamber.

WE ſhall here give a ſhort deſcription of this optical invention; for tho' it is very common, it is alſo very pleaſing, and though almoſt every one has ſeen it, every one knows not how to conſtruct it.

by changing the light to the left ſide, it has immediately appeared in relief. It ſtill, however, remains to be explained, why we ſee it alternately hollow and prominent, without changing either the ſituation or the light. Perhaps it is in the ſight itſelf that we muſt look for the cauſe of this phenomenon; and this ſeems the more probable, as all theſe appearances are not diſcernable by all perſons.

A phenomenon like this will appear to a ſuperficial obſerver a very trifling matter: but the philoſopher, who is deſirous of explaining all the appearances of nature, will find it attended with no trifling difficulties. It is, moreover, by inveſtigating the cauſes of phenomena ſeemingly inſignificant, that the moſt important diſcoveries are ſometimes made.

Make

Make a circular hole in the ſhutter of a window, from whence there is a proſpect of the fields, or any other object not too near; and in this hole place a convex glaſs, either double or ſingle, whoſe focus is at the diſtance of five or ſix feet *. Take care that no light enter the room but by this glaſs: at a diſtance from it, equal to that of its focus, place a paſteboard, covered with the whiteſt paper †; let it be two feet and a half long, and eighteen or twenty inches high: bend the length of it inwards, to the form of part of a circle, whoſe diameter is equal to double the focal diſtance of the glaſs. Then fix it on

* The diſtance ſhould not be leſs than three feet; for if it be, the images will be too ſmall, and there will not be ſufficient room for the ſpectators to ſtand conveniently. On the other hand the focus ſhould never be more than 15 or 20 feet, for then the images will be obſcure, and the colouring faint. The beſt diſtance is from 6 to 12 feet.

† This paper ſhould have a black border, to prevent any of the ſide rays from diſturbing the picture.

a frame of the ſame figure, and put it on a moveable foot, that it may be eaſily fixed at that exact diſtance from the glaſs where the objects paint themſelves to the greateſt perfection. When it is thus placed, all the objects that are in the front of the window will be painted on the paper, in an inverted poſition *, with the greateſt regularity and in the moſt natural colours.

If you place a moveable mirror without the window, by turning it more or leſs,

* This inverted poſition of the images may be deemed an imperfection, but it is eaſily remedied: for if you ſtand above the board on which they are received, and look down on it, they will appear in their natural poſition: or if you ſtand before it, and placing a common mirror againſt your breaſt in an oblique direction, look down in it; you will there ſee the images erect, and they will receive an additional luſtre from the reflection of the glaſs; or place two lenſes, in a tube that draws out; or, laſtly, if you place a large concave mirror at a proper diſtance before the picture, it will appear before the mirror, in the air, and in an erect poſition.

you

you will have on the paper all the objects that are on each side of the window *.

If instead of placing the mirror without the window you place it in the room, and above the hole (which must then be made near the top of the shutter), you may receive the representation on a paper placed horizontally on a table; and draw, at your leisure, all the objects that are there painted.

Nothing can be more pleasing than this Recreation, especially when the objects are strongly enlightened by the sun: and

* There is another method of making the dark chamber, which is by a scioptric ball, that is, a ball of wood, through which a hole is made, in which hole a lens is fixed: this ball is placed in wooden frame, in which it turns freely round. The frame is fixed to the hole in the shutter, and the ball, by turning about, answers, in great part, the use of the mirror on the outside of the window. If the hole in the window be no bigger than a pea, the objects will be represented without any lens.

not only land prospects, but a sea-port, when the water is somewhat agitated, or at the setting of the sun, presents a very delightful appearance.

This representation affords the most perfect model for painters, as well for the tone of colours, as that degradation of shades, occasioned by the interposition of the air, which has been so justly expressed by some modern painters.

It is necessary that the paper have a circular form, for otherwise, when the center of it was in the focus of the glass, the two sides would be beyond it, and consequently the images would be confused. If the frame were contrived of a spherical figure, and the glass were in its center, the representation would be still more accurate. If the object without be at the distance of twice the focal length of the glass, the image in the room will be of the same magnitude with the object.

The

The lights, shades, and colours in the camera obscura appear not only just, but, by the images being reduced to a smaller compass, much stronger than in nature: add to this, that these pictures exceed all others by representing the motion of the several objects: thus we see the animals walk, run, or fly, the clouds float in the air, the leaves quiver, the waves roll, &c. and all in strict conformity to the laws of nature. The best situation for a dark chamber is directly north, and the best time of the day is noon.

RECREATION VI.

To show the spots on the sun's disk, by its image in the camera obscura.

PUT the object-glass of a ten or twelve foot telescope into the scioptric ball, and turn it about till it be directly oppo-

RECREATION VIII.

The portable camera obſcura.

THE great pleaſure produced by the camera obſcura in the common form, has excited ſeveral to render it more univerſally uſeful by making it portable; eaſily fixed on any ſpot, and adapted to every proſpect. We ſhall not here examine the merits of the various ſorts that have been invented, among which there are doubtleſs ſeveral highly ingenious; but content ourſelves with deſcribing one that may have ſome advantages not to be found in others *.

Let ABCD (Pl. III. Fig. 2.) be a frame of wood, of two feet long and about twenty inches wide; let its four ſides be two inches and a half thick, and firmly joined together. In a groove formed in this

* This ſort of portable camera appears to be the invention of M. Guyot.

frame

frame place a plate of clear glaſs, E *. To each of the corners of this frame join a leg, with a hinge, that it may turn up, under the table. To the under part of the frame join four pieces of light wood, as H, which muſt alſo have hinges to fold up; and obſerve that when they are let down, as in the figure, they muſt cloſely join, by means of hooks, it being quite neceſſary that no light enter the box †.

To that juſt deſcribed, there muſt be added a ſmaller box M, in which muſt be an inclined mirror N, and in one of its ſides a moveable tube O, five or ſix ſix inches long. This tube muſt be furniſhed with a convex glaſs, the focus of which, by the reflection of the mirror, muſt reach the glaſs E in the frame.

* If the upper ſide of the glaſs were convex, it would be ſtill better.

† The inſide of the box may be lined with black cloth, to make it as dark as poſſible.

There

There muſt alſo be a covering of black ſtuff, in form of a tent, to place over the top of the frame, by means of four little poles that go into holes in the corners of it. There muſt be an opening to this tent on the ſide A B, by a curtain to be drawn up, and which you are to let down over you, when you place yourſelf under it; that no light may enter. The three other ſides ſhould hang down ſome inches over the frame.

This camera is, indeed, ſomething more cumberſome than thoſe that have been hitherto invented; and yet, if properly made, it will not weigh more than twenty to five-and-twenty pounds. On the other hand, it is much more convenient; for as the coloured rays of objects paint themſelves on the bottom of the glaſs in the frame, you may draw them without having your hand between the rays and their image.

When

When you have placed the frame on a ſpot a little elevated, that nothing may intercept the rays from falling on the glaſs in the tube, you fix a ſheet of tranſparent varniſhed paper on the glaſs in the frame, by means of wax at its corners. Then placing yourſelf under the curtain, you trace on the paper all the outlines of the objects there repreſented, and if you think fit, you may alſo mark the extent of the ſhadows. If you want only the outlines, you may lay a thin plate of glaſs on that in the frame, and trace the ſtrokes with a pencil and carmine. After which you muſt dip a ſheet of paper in water, without making it too wet, and ſpreading it lightly over that glaſs, you will have the impreſſion of the deſign there drawn.

Note, By each of theſe methods you will have the objects either in their natural poſition, or reverſed; which will be an advantage when the deſign is to be engraved, and you would have it then appear in the natural poſition.

In

In uſing this machine, you ſhould make choice of thoſe objects on which the ſun then ſhines, as the appearance of the ſhadows adds greatly to the beauty of the deſign. There are, however, circumſtances in which it is to be avoided, as when you would paint a riſing or ſetting ſun, &c.

RECREATION IX.

The magic lantern.

THIS very remarkable machine, which is now known over all the world, cauſed great aſtoniſhment at its origin. It is ſtill beheld with pleaſing admiration, and the ſpectator very frequently contents himſelf with wondering at its effects, without endeavouring to inveſtigate their cauſe. The invention of this ingenious illuſion is attributed to the celebrated P. Kirker, who has publiſhed, on various ſciences, works equally learned, curious, and entertaining.

The

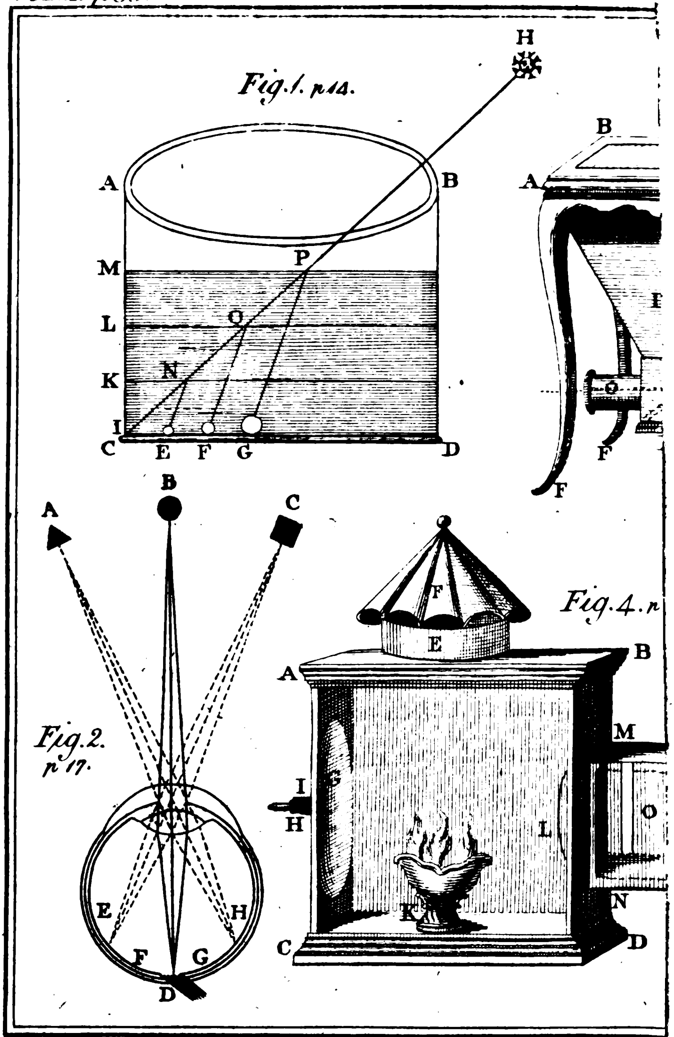


Fig. 1. p. 14.
H
A
B
M
P
L
O
K
N
I
C
E
F
G
D
Fig. 2. p. 17.
B
A
C
E
H
F
G
D
Fig. 4. p
F
E
A
B
M
I
G
H
L
O
K
N
C
D

The defign of this machine is to reprefent at large, on a cloth or board, placed in the dark, the images of fmall objects, painted with tranfparent colours on plates of glafs.

Its conftruction is as follows. Let ABCD (Pl. III. Fig. 3.) be a tin box, eight inches high, ten long; and fix wide (or any other fimilar dimenfions). At the top muft be a funnel E, of four inches in diameter, with a cover F, which, at the fame time that it gives a paffage to the fmoke, prevents the light from coming out of the box.

On the fide AC there is a door, by which is adjufted a concave mirror G, of metal or tin, and of five inches diameter; being part of a fphere whofe diameter is eighteen inches. This mirror muft be fo difpofed that it may be pufhed forward or drawn back by means of the handle H, that enters the tin tube I, which is foldered to the door.

In the middle of the box muft be placed a low tin lamp K, which is to be moveable. It fhould have three or four lights, that muft be at the height of the focus of the mirror G.

In the fide BD, and oppofite to the mirror, there muft be an aperture of three inches wide and two inches and a half high, in which is to be fixed a convex glafs L, of the fame dimenfion *, whofe focus muft be from four inches and a half to five inches, fo that the lamp may be

* I prefer this form for the glafs (fays M. Guyot) that the picture thrown upon the cloth may have the fame form, which is much preferable to a circular aperture, through which the figures can never be completely feen but when they are at the center of the glafs. It is furprifing that this imperfection has been fuffered to continue fo long, when it is fo eafily remedied.

placed

placed both in its focus, and in that of the concave mirror.

On the ſame ſide is to be placed a piece of tin M N, of four inches and a half ſquare, having an opening at the ſides of about four inches and a half high, and a quarter of an inch wide. Through this opening or groove are to paſs the glaſſes, on which are painted the figures that are to be ſeen on the cloth. In this tin piece, and oppoſite to the glaſs L, let there be an aperture of three inches and a quarter long, and two inches and a quarter high, to which muſt be adjuſted a tube O, of the ſame form, and ſix inches long. This tube is to be fixed into the piece M N. Another tube, ſix inches long, and moveable, muſt enter that juſt mentioned, in which muſt be placed two convex lenſes, P and Q; that of P may have a focus of about three inches, and that of Q, which is to be placed at the extremity of the tube, one of ten or twelve inches. The diſtance between theſe glaſſes is to be regulated by their foci. Between theſe glaſſes there muſt be placed a paſteboard R, in which is an aperture of an inch wide, and 4-5ths of an inch high. By placing this tube farther in or out of the other, the images on the cloth will appear larger or ſmaller.

From what has been ſaid of the preceding machines, the conſtruction of this will be eaſily underſtood. The foci of the concave mirror, and the lens L, meeting in the flame of the lamp, they together throw a ſtrong light on the figures painted on the glaſſes that paſs through the groove M N, and by that means render their colours diſtinct on the cloth. The rays from thoſe glaſſes paſſing through the lens P are collected by the aperture in the paſteboard R, and conveyed to the lens Q, by which they are thrown on the cloth.

The lantern being thus adjuſted, you muſt provide plates of clear glaſs, of twelve or fifteen inches long, and three inches wide, which are to be placed in thin frames, that they may paſs freely through the groove MN, after being painted in the manner we ſhall now deſcribe.

Method of painting the glaſſes for the lantern.

Draw on a paper the ſubject you intend to paint, and fix it at each end to the glaſs. Provide a varniſh with which you have mixed ſome black paint, and with a fine pencil draw on the other ſide of the glaſs, with very light touches, the deſign drawn on the paper. If you are deſirous of making the painting as perfect as poſſible, you ſhould draw ſome of the outlines in their proper colours, provided they are the ſtrongeſt tints of thoſe colours that are uſed. When the outlines are dry, you colour the figures with their proper tints or degradations; and thoſe colours will not peel off, if you temper them with a ſtrong white varniſh *. You are then to ſhade them with black mixed with the ſame varniſh, or with biſtre, as you find convenient. You may alſo leave ſtrong lights in ſome parts, without any colours, in order to produce a more ſtriking effect. Obſerve, in particular, not to uſe more than four or five colours, ſuch as blue, red, green, and yellow. You ſhould employ however a great variety of tints, to give your painting a more natural air, without which they will repreſent vulgar objects, which are by no means the more pleaſing becauſe they are gawdy.

When the lamp in this lantern is lighted, and by drawing out the tube to a proper length, the figures painted on the glaſs appear bright and well deſigned, the ſpectator cannot fail of being highly enter-

* All thoſe colours that are not terreſtrial, as Pruſſian blue, carmine, calcined verdigris, &c. may be uſed to advantage, when tempered with a proper varniſh.

tained by the ſucceſſion of natural or groteſque figures that are painted on the glaſſes.

This piece of optics may be rendered much more amuſing, and at the ſame time more marvellous, by preparing figures to which different natural motions may be given *, which every one may perform according to his own taſte; either by movements in the figures themſelves, or by painting the ſubject on two glaſſes, and paſſing them at the ſame time through the groove, as will be ſeen in the next Recreation.

* There are in the Philoſophical Eſſays of M. Muſchenbroek, different methods of performing all theſe various movements, by ſome mechanical contrivances that are not difficult to execute.

RECREATION X.

To represent a tempest by the magic lantern.

PROVIDE two plates of glass, whose frames are so thin that they may both pass freely through the groove M N, at the same time (Pl. III. Fig. 3.)

On one of these glasses you are to paint the appearance of the sea, from the slightest agitation to the most violent commotion. Representing from A to B (Pl. IV. Fig. 1.) a calm, from B to C a small agitation, with some clouds, and so on to F and G, which should exhibit a furious storm. Observe, that these representations are not to be distinct, but run into each other, that they may form a natural gradation: remember also, that great part of the effect depends on the perfection of the painting, and the picturesque appearance of the design.

On the other glass (Fig. 2.) you are to paint vessels of different forms and dimenſions, and in different directions, together with the appearance of clouds in the tempeſtuous parts.

You are then to paſs the glaſs (Fig. 1.) ſlowly through the groove, and when you come to that part where the ſtorm begins, you are to move the glaſs gently up and down, which will give it the appearance of a ſea that begins to be agitated; and ſo increaſe the motion till you come to the height of the ſtorm. At the ſame time you are to introduce the other glaſs with the ſhips, and moving that in like manner, you will have a natural repreſentation of the ſea, and of ſhips in a calm and in a ſtorm. As you draw the glaſſes ſlowly back, the tempeſt will ſeem to ſubſide, the ſky grow clear, and the ſhips glide gently o'er the waves.

This effect of the magic lantern muſt certainly afford more pleaſure and ſurprize, than to ſee figures, frequently badly painted,

painted, appear one after the other in the midst of a luminous circle, as in a medal; whose form, besides being disgustful, prevents you from seeing any two figures together, without the head and legs of one of them being entirely hid: an inconvenience that is avoided by this new method, even when you make use of the common figures.

By means of two glasses disposed in this manner you may likewise represent a battle, or sea fight, and numberless other subjects, that every one will contrive according to his own taste. They may be also made to represent some remarkable or ludicrous action between different persons, and many other amusements that a lively imagination will easily suggest. The instance we here give (says M. Guyot) being intended merely as an example, and to shew that this machine is capable of producing much more remarkable effects than have been hitherto exhibited.

RECRE-

RECREATION XI.

The nebulous magic lantern.

THE light of the magic lantern, and the colour of images, may not only be painted on a cloth, but alſo reflected by a cloud of ſmoke.

Provide a box of wood or paſteboard AB (Pl. IV. Fig. 3.) of about four feet high, and of ſeven or eight inches ſquare at bottom, but diminiſhing as it aſcends, ſo that its aperture at top is but ſix inches long, and half an inch wide. At the bottom of this box there muſt be a door that ſhuts quite cloſe, by which you are to place in the box a chafing-diſh with hot coals, on which is to be thrown incenſe, whoſe ſmoke goes out in a cloud at the top of the box. It is on this cloud that you are to throw the light that comes out of the lantern, and which you bring into a ſmaller compaſs by drawing out the moveable tube.

tube. The common figures will here ſerve. It is remarkable in this repreſentation that the motion of the ſmoke does not at all change the figures, which appear ſo conſpicuous that the ſpectator thinks he can graſp them with his hand.

Note, In this experiment ſome of the rays paſſing through the ſmoke the repreſentation will be much leſs vivid than on the cloth; and if care be not taken to reduce the light to its ſmalleſt focus, it will be ſtill more imperfect.

RECREATION XII.

To produce the appearance of a phantom, upon a pedeſtal placed on the middle of a table.

ENCLOSE a common ſmall magic lantern in a box A B C D (Plate IV. Fig. 4.) that is large enough to contain alſo an inclined mirror M, which muſt be moveable, that it may reflect the

cone

cone of light thrown on it by the lantern, in ſuch manner that it may paſs out at the aperture made in the top of the box. There ſhould be a flap with hinges to cover the opening, that the inſide of the box may not be ſeen when the experiment is not making. This aperture ſhould likewiſe be oval, and of a ſize adapted to the cone of light that is to paſs through it.

There muſt be holes made in that part of the box which is over the lantern, to let out the ſmoke; and over that part muſt be placed a chafing-diſh of an oblong figure, and large enough to hold ſeveral lighted coals *.

There muſt alſo be a glaſs that will aſcend and deſcend at pleaſure in the vertical groove *a b*. To this glaſs let there be fixed

* This chafingdiſh may be encloſed in a painted tin box of about a foot high, with an aperture at top ſomething like Fig. 3. It ſhould ſtand on four ſhort feet, to give room for the ſmoke of the lamp to paſs out.

a cord

a cord, that going over a pulley *e*, paſſes out of the box at the ſide CD, by which the glaſs may be drawn up, and will deſcend by its own weight.

On this glaſs may be painted a ſpectre, or any other more pleaſing figure. Obſerve that the figures muſt be contracted in drawing, as the cloud of ſmoke does not cut the cone of light at right angles, and therefore the figures will appear longer than they do on the glaſs.

After you have lighted the lamp in the lantern, and put the mirror in a proper direction, you place the box or pedeſtal ABCD on a table, and putting the chafing-diſh in it, throw ſome incenſe in powder on the coals. You then open a trap door, and let down the glaſs ſlowly; and when you perceive the ſmoke diminiſh you draw up the glaſs, that the figure may diſappear, and ſhut the trap door. This appearance will occaſion no ſmall ſurprize, as the ſpec-

tre

tre will ſeem to riſe gradually out of the pedeſtal, and on drawing up the glaſs will diſappear in an inſtant. Obſerve, that when you exhibit this Recreation you muſt put out all the lights in the room; and the box ſhould be placed on a high table, that the ſpectators may not perceive the aperture by which the light comes out. Tho' we have mentioned a ſmall magic lantern, yet the whole apparatus may be ſo enlarged, that the phantom may appear of a formidable ſize.

By having glaſſes properly painted, you may alſo produce the image of a flower, or a card, &c. like one you have burnt, and caſt the aſhes into the fire with the incenſe, and by that means pretend to make the image riſe out of the aſhes; with many other devices that every one may contrive of that kind which ſhall pleaſe him beſt.

RECREATION XIII.

The magical theatre.

BY making ſome few additions to the magic lantern with the ſquare tube *, uſed in the ninth Recreation, various ſcenes, characters, and decorations of a theatre may be lively repreſented.

Let there be made a wooden box ABCD (Plate IV. Fig. 5.) a foot and a half long, fifteen inches high, and ten wide. Let it be placed on a ſtand EF, that muſt go round it, and by which it may be fixed with two ſcrews to a table. Place over it a tin cover, as in the common lantern.

Make an opening in its two narroweſt ſides; in one of which place the tube H,

* It is quite neceſſary to make the lantern much larger than common, that the objects painted on the glaſſes, being of a larger ſize, may be repreſented with greater preciſion, and conſequently their ſeveral characters more ſtrongly marked.

and

and in the other the tube I; let each of them be ſix inches wide, and five inches high; in each of theſe tubes place another that is moveable, in order to bring the glaſſes, or concave mirror, that are contained in them, to a proper diſtance; as will be explained hereafter.

In the middle of the bottom of this box place a tin lamp, M, which muſt be moveable in a groove, that it may be placed at a proper diſtance with regard to the glaſſes and mirror: this lamp ſhould have five or ſix lights, each of them about an inch long. See the Figure.

At the beginning of the tube H, toward the part N, make an opening of an inch wide, which muſt croſs it laterally: another of three quarters of an inch, that muſt croſs it vertically, and be nearer the box than the firſt; and a third of half an inch, that muſt be before the firſt.

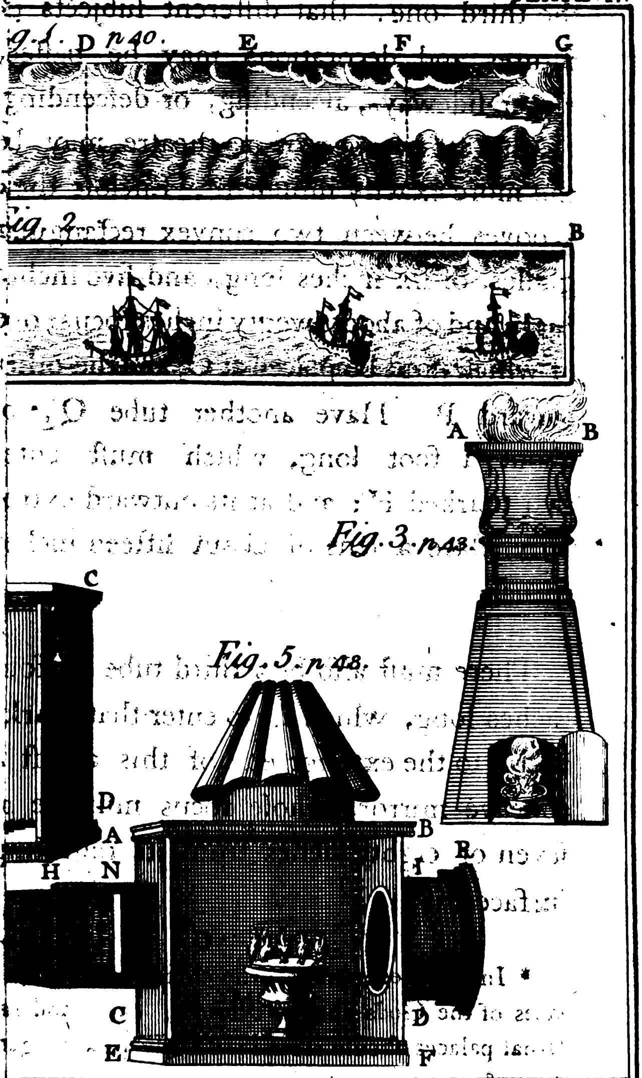
The opening made laterally muſt have three or four grooves, the ſecond two, and the third one: that different subjects of figures and decorations may be passed, either sideways, ascending, or descending, so that the scenes of a theatre may be the more exactly imitated*. Enclose these grooves between two convex rectangular glasses, of six inches long, and five inches high, and of about twenty inches focus; one of which must be placed at O, and the other toward P. Have another tube Q, of about a foot long, which must enter that marked H; and at its outward extremity place a lens of about fifteen inches focus.

There must also be a third tube R, four inches long, which is to enter that marked I: to the exterior end of this adjust a concave mirror, whose focus must be at seven or eight inches from its reflecting surface.

* In the decorations, the clouds and the palaces of the Gods should descend; caves and infernal palaces should ascend; earthly palaces, gardens, &c. enter at the sides.

This

PLATE. IV.



J. Lodge sculp.

This magic lanthorn being thus adj[illegible] ed, nothing more necessary than to [illegible] ude glasses, painted with such fig[illegible] you would represent [illegible] [illegible]

[illegible]

It [illegible] entertainment [illegible]

[illegible]

This magic lanthorn being thus adjuſted, nothing more is neceſſary than to provide glaſſes, painted with ſuch ſubjects as you would repreſent, according to the grooves they are to enter. The lamp is then to be lighted, and placing a glaſs in one of the groves, you draw out the moveable tubes till the object paints itſelf on a cloth to the moſt advantage: by which you determine the diſtance of the lantern, and the ſize of the image. You then make a hole in the partition of that ſize, and fix in it a plate of clear glaſs, over which you paſte a very thin paper, which muſt be varniſhed, that it may be as tranſparent as poſſible.

It is on this paper that are to be exhibited the images of all thoſe objects, that by paſſing ſucceſſively through the grooves, are to repreſent a theatric entertainment. This exhibition will be the more agreeable, as the magic lantern being concealed behind the partition, the cauſe of the illusion cannot by any means be discovered.

In order to show more clearly in what manner a subject of this sort should be painted, and the glasses disposed, we will here make choice of the siege of Troy for a theatric subject; in which will be found all the incidents necessary to the exhibition of any other subject whatever.

In the first act, the theatre may represent, on one side the ramparts of Troy, toward the back part the Grecian camp, and at a further distance, the sea and the isle of Tenedos. We will suppose the time to be that when the Greeks feigned to raise the siege, and embarked, leaving behind them the wooden horse, in which were contained the Grecian soldiers.

On a glass, therefore, of the same width with the aperture made in the side A C of the box, you are to paint a deep blue curtain,

tain, lightly charged with ornaments, quite tranſparent. This glaſs is to be placed in the firſt vertical groove, ſo that by letting it gently down *, its image may appear to riſe in the ſame manner as the curtain of a theatre.

You muſt have ſeveral glaſſes of a proper ſize to paſs through the horizontal grooves, and of different lengths according to the extent of the ſubject. You may paint

On the firſt, the walls of Troy.

On the ſecond, the Grecian camp.

On the third, the ſea, the iſle of Tenedos, and a ſerene ſky.

On the fourth, the Grecian troops, by detached figures.

On the fifth, other troops, diſpoſed in battalions, and placed at a diſtance.

* All the glaſſes that are to riſe and deſcend muſt be bordered with thin pieces of wood, and ſo exactly fill the grooves, that they may not ſlide down of themſelves.

On the sixth, divers vessels, which as the glass advances in the groove diminish in size.

On the seventh, the wooden horse and Sinon.

On the eighth, Trojan men and women.

These glasses being properly painted *, you place in the horizontal grooves the first, second, third, and fourth. Then draw up the curtain, by letting down the glass on which it is painted, and draw away gently the fourth glass, and after that the second; then advance, very gently, the fifth, that represents the embarkment, and pass it quite through. Next pass, the opposite way, the sixth, which represents the Grecian fleet. The objects painted on the fourth, fifth, and sixth quite disappearing, you are to advance the seventh, on which is painted the

* Unless you can procure glasses well painted, it were better to represent some comic subject, where common paintings may suffice.

wooden

wooden horse; and at the same time the eighth, where the Trojans will appear to draw the horse into the city. The curtain is then to be let down, that you may withdraw the scenes of the first act, and place in the grooves those that are to compose the second.

In the second act may be represented the interior part of the city of Troy: on one side may be seen the wooden horse, and in the back part the temple of Pallas. The glasses for this act may be painted in the following manner.

On the first, may be palaces and houses, representing the inside of a city.

On the second, the temple of Pallas in the centre, with a clear night and the moon. In the front may be seen the wooden horse, that the Trojans have placed near the temple of Pallas.

On the the third, a troop of Greeks, with Sinon at their head, who are going to open the gates of the city to the Grecians.

On the fourth, different troops of armed Greeks; painted on a long glaſs, to afford variety.

On the fifth, ſeveral troops of Trojans.

On the ſixth, various appearances of fire and ſmoke, ſo diſpoſed, that this glaſs being drawn up above the others, the objects painted on the firſt glaſs, may appear in a conflagration.

Before you draw up the curtain you ſhould place the firſt and ſecond glaſſes. You then paſs the whole third glaſs ſlowly; a little after, the fourth, on which are painted the different bodies of armed Greeks, and at the ſame time, from the oppoſite ſide, the ſixth glaſs, that repreſents the Trojan troops; obſerving to move them ſlowly both in advancing and retreating, to imitate a combat *. Then

* He that moves the glaſſes, ſeeing the effect they produce, is the better able to render the repreſentation as natural as poſſible.

draw

draw up, by degrees, the ſixth, on which are painted the fire, flame, and ſmoke, ſo that the palaces and houſes painted on the firſt glaſs, may appear to take fire gradually, and at laſt preſent a general conflagration. After having repreſented theſe incidents with the greateſt attention, you let fall the curtain to prepare for the third act.

In the third act may be repreſented the inſide of Priam's palace, where is ſeen an altar, round which ſeveral Trojan princeſſes appear, who have fled thither for ſafety.

On the firſt glaſs may be painted the palace.

On the ſecond, a view of the back part of the palace, with the altar.

On the third, Priam with ſeveral Trojan men and women.

On the fourth, Pyrrhus, and a troop of Greeks.

On the fifth, the ſame actors, with the palace in flames.

On

On the ſixth, A conflagration.

The two firſt glaſſes which are to be drawn up, ſhould be placed before you raiſe the curtain. Then paſs the third; next advance the fourth, which being drawn up, diſcovers on the fifth the palace in flames, then drawing up the ſixth, let down the firſt, that the palace may appear entirely deſtroyed by the conflagration.

The fourth act may repreſent the environs of Troy, with a diſtant proſpect of the ſea. The firſt and third glaſſes of the firſt act may be here uſed, to which may be added a third, repreſenting Eneas bearing his father Anchiſes, followed by his ſon Iulus, and ſome Trojans. With this glaſs may be repreſented the flight of the Trojans, and the embarkment of Eneas, with another glaſs, on which are painted certain veſſels.

To this act the following ſcenes may be added. The cave of Æolus; the back part

part of the cave; Æolus; the winds; Juno in her chariot.

The fifth act should represent the open sea, with the fleet of Eneas sailing for Italy.

On the first glass must be painted the sea, as in the tenth Recreation, or else the waves should be imitated by another glass under the first.

On the second, The Trojan fleet.

On the third, Neptune in his car.

On the fourth, the palace of Jupiter.

On the fifth, the inside of the palace; the Gods assembled in council, with Venus, obtaining leave of Jupiter for Eneas to land in Italy.

After having placed the first glass, that represents a calm sea, the curtain is raised, and the second scene is advanced, which contains the Trojan fleet. The first is then brought forward, to represent a violent

lent tempeſt: then raiſing the third glaſs, Neptune appears, who commands the waves to be ſtill, which is done by making the tempeſt ſubſide by degrees. The fleet then advances, and paſſes over the whole theatre: preſently after the fourth and fifth ſcenes deſcend, that repreſent Olympus, and finiſh the exhibition.

Note, We muſt here repeat, that if you would repreſent a ſubject of this ſort to advantage, it is quite neceſſary that the glaſſes be well painted: and thoſe that are to be in front, ſhould be in ſtronger and more opaque colours, that the images of thoſe behind may not appear mixed with them, which will be the caſe if they are all equally tranſparent.

The glaſſes ſhould alſo be of different lengths, that ſome being placed before the others are drawn away, their extremities may not be perceived.

The

The larger these ſubjects are repreſented the better effect they will have: the front of the theatre ſhould appear to be about three feet wide: and, as we have ſaid elſewhere, if ſome parts of the figures were moveable it would ſtill add to the variety of the entertainment.

This and moſt of the other Recreations we have here given in the two firſt parts of Optics, appear to have been invented by M. Guyot, who has taken no ſmall pains in the improvement of this ſort of recreations.

CATOP-

CATOPTRICS.

CATOPTRICS is that part of optics which explains the properties of reflected light, and particularly, that which is reflected from mirrors.

DEFINITIONS.

1. Every polished body that reflects the rays of light is called a mirror, whether its surface be plane, spherical, conical, cylindric, or of any other form whatever.

2. Of mirrors there are three principally used in optical experiments, which are, the plane mirror, G H I, (Plate V. Fig. 1.) the spherical convex mirror, G H I, (Plate V. Fig. 2.) and the spherical concave mirror, G H I, (Plate V. Fig. 3.)

3. The point K, (Plate V. Fig. 2 and 3.) round which the reflecting surface of a spherical mirror is described, is called its centre. The line K H, drawn from its

center

center perpendicular to its two surfaces, is the axis of the mirror, and the point H, to which that line is drawn, is its vortex.

4. The distance between the lines A G and B G, (Plate V. Fig. 1.) is called the angle of incidence, and the distance between B G and C G is the angle of reflection.

APHORISMS.

I. In a plain Mirror.

1. The image D F, (Plate V. Fig. 1.) will appear as far behind the mirror, as the object A C is before it.

2. The image will appear of the same size, and in the same position as the object.

3. Every such mirror will reflect the image of an object of twice its own length and breadth.

4. If the object be an opaque body, and its rays fall on the mirror nearly in direct lines, there will be only one image visible, which

the mirror, inverted and diminiſhed, as DEF, (Plate V. Fig. 4.)

5. The ſuns rays falling on a concave mirror, and being parallel, will be collected in a focus at half the diſtance of its center, where their heat will be augmented in proportion of the ſurface of the mirror to that of the focal ſpot.

6. If a luminous body be placed in the focus of a concave mirror, its rays being reflected in parallel lines, will ſtrongly enlighten a ſpace of the ſame dimenſion with the mirror, at a great diſtance. If the luminous object be placed nearer than the focus, its rays will diverge, and conſequently enlighten a larger ſpace *.

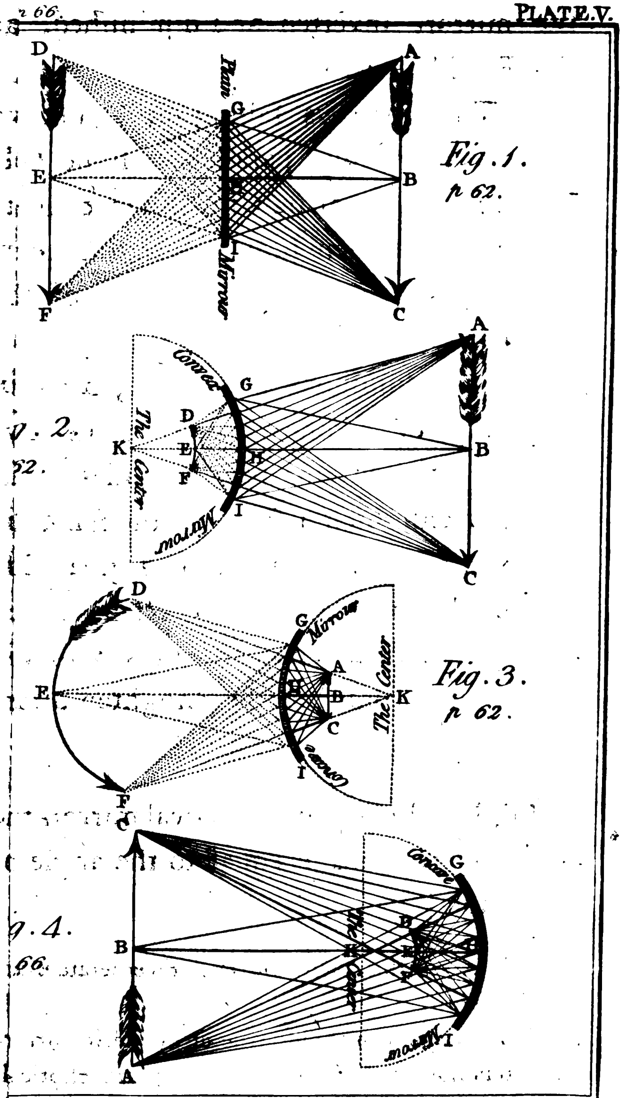
IV. In all plane and ſpherical mirrors the angle of incidence is equal to the angle of reflection †.

* It is on this principle that reverberators are conſtructed.

† This aphoriſm holds true of cylindric mirrors alſo, but not of thoſe whoſe ſurfaces are eliptical, parabolic, &c.

RECRE-

p 66. PLATE.V.



J. Lodge Sculp.

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RECRE-

PLATE. V.

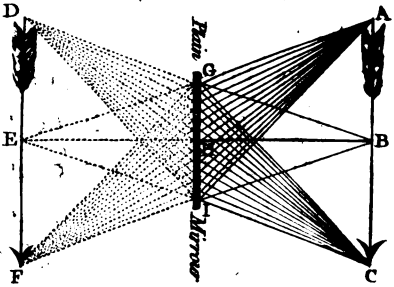
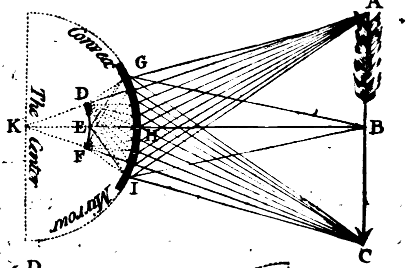


Fig. 1.
p 62.



g. 2.
62.

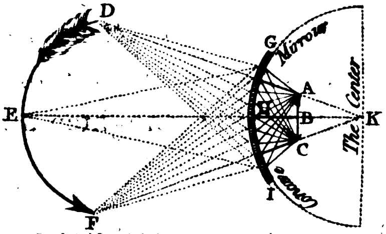
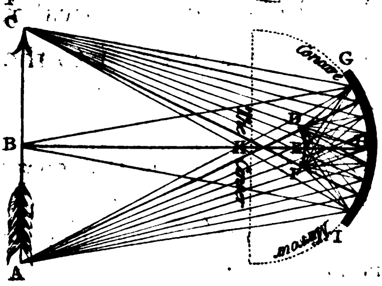


Fig. 3.
p 62.



g. 4.
66.

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RECREATION XIV.

The boundless gallery.

CONSTRUCT a box A B, (Plate VI. Fig. 1.) of about a foot long, eight inches wide, and six high; or what other dimension you shall think fit, provided it does not greatly vary from these proportions.

On the inside of this box, and against each of its opposite ends A and B, place a mirror of the same size. Take off the quicksilver from the mirror that you place at B, for about an inch and an half, at the part C, where you are to make a hole in the box of the same size, by which you may easily view its inside. Cover the top of the box with a frame, in which must be placed a transparent glass, covered with gauze, on the side next the inner part of the box. Let there be two grooves at the parts E and F to receive the two painted scenes hereafter mentioned. On two pieces of cut pasteboard let there be skilfully painted, on both sides (see Fig. 2. and 3.) any subject you think proper; as woods, gardens, bowers, colonades, &c. and on two other pasteboards, the same subjects on one side only; observing that there ought to be on one of them some object relative to the subject placed at A, that the mirror placed at D may not reflect the hole at C on the opposite side.

Place the two boards painted on both sides (Fig. 4. and 5.) in the grooves E and F; and those that are painted on one side only, against the opposite mirrors C and D; and then cover the box with its transparent top. This box should be placed in a strong light to have a good effect.

When the eye is placed at C, and views the objects on the inside of the box, of which some, as we have said, are painted on both sides, they are successively reflect- from one mirror to the other; and if,

for

for example, the painting consists of trees, they will appear like a very long vista, of which the eye cannot discern the end: for each of the mirrors repeating the objects, continually more faintly, contribute greatly to augment the illusion.

RECREATION XV.

The four magical mirrors.

TAKE a square box ABCD, (Plate VI. Fig. 4.) of about six inches long, and twelve high *; cover the inside of it with four plane mirrors, which must be placed perpendicular to the bottom of the box CHFD.

Place certain objects in relief on the bottom of this box; suppose, for example, a piece of fortification, (as Fig. 5.) with tents, soldiers, &c. or any other subject

* We do not mean to limit the box to this size; any other may be used, provided, however, that it have nearly the same proportions.

that you judge will produce an agreeable effect by its disposition, when repeatedly reflected by the mirrors.

On the top of this box place a frame of glass, in form of the bottom part of a pyramid, whose base A G E B, is equal to the size of the box: its top I L M N, must form a square of six inches, and should not be more than four or five inches higher than the box. Cover the four sides of this frame with a gauze, that the inside may not be visible but at the top I L M N, which should be covered with a transparent glass.

When you look into this box through the glass I L M N, the mirrors that are diametrically opposite each other, mutually reflecting the figures enclosed, the eye beholds a boundless extent, completely covered with these objects; and if they are properly disposed, as in the example here given, in Fig. 5. the illusion will occasion

Fig. 1. p 67.

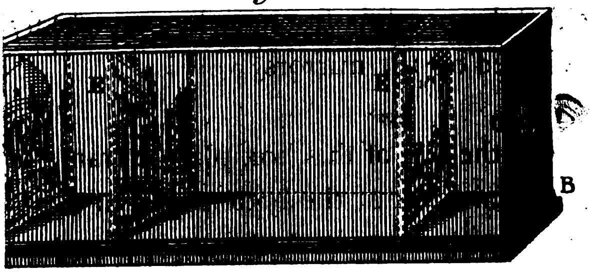


Fig. 2. p 68.

Fig. 3. p 68.

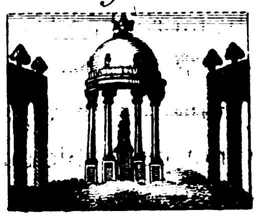


Fig. 5. p 70.

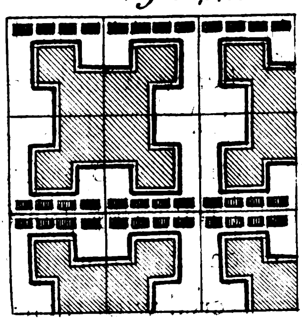
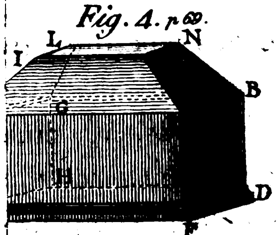


Fig. 4. p 69.



J. Lodge Sculp.

occaſion no ſmall ſurprize, and afford great entertainment.

Note, The nearer the opening ILMN is to the top of the box, the greater will be the apparent extent of the ſubject. The ſame will happen if the four mirrors placed on the ſides of the box be more elevated. The objects, by either of theſe diſpoſitions, will appear to be repeated nine, twenty-five, forty-nine times, &c. by taking always the ſquare of the odd numbers of the arithmetic progreſſion 3, 5, 7, 9, &c. as is very eaſy to conceive, if we remember that the ſubject encloſed in the box is always in the center of a ſquare, compoſed of ſeveral others, equal to that which forms the bottom of the box.

Other pieces of the ſame kind (that is viewed from above) may be contrived, in which mirrors may be placed perpendicular on a triangular, pentagon, or

 hexagon,

hexagon, (that is, a three, five, or six-sided) plane. All these different dispositions, properly directed as well with regard to the choice as position of the objects, will constantly produce very remarkable and pleasing illusions.

If instead of placing the mirrors perpendicular, they were to incline equally, so as to form part of a reversed pyramid, the subject placed in the box would then have the appearance of a very extensive globular or many-sided figure.

RECREATION XVI.

The enchanted palace.

ON the hexagonal or six-sided plane ABCDEF (Pl. VII. Fig. 1.) draw six semi-diameters GA, GB, GC, GD, GE, GF, and on each of these place perpendicularly, two plane mirrors, which must join

join exactly at the center G *. Decorate the exterior boundary of this piece (which is at the extremity of the angles of the hexagon) with six columns, that at the same time serve to support the mirrors, by grooves formed on their inner sides. (See the profile, Fig. 1.) Add to these columns their entablatures, and cover the edifice in such manner as you shall think proper.

In each one of these six triangular spaces, contained between two mirrors, place little figures of pasteboard, in relief, representing such objects as when seen in an hexagonal form will produce an agreeable effect. To these add small figures of enamel; and take particular care to conceal, by some object that has relation to the subject, the place where the mirrors join, which, as we have said before, all meet in the common center G.

* These mirrors, placed back to back, must be as thin as possible.

When

When you look into any one of the ſix openings of this magical palace, the objects there contained being repeated ſix times, will ſeem entirely to fill up the whole of the building. This illuſion will appear very remarkable; eſpecially if the objects made choice of are properly adapted to the effect that is to be produced by the mirrors.

Note, If you place between two of theſe mirrors part of a fortification, as a curtain and two demibaſtions, you will ſee an entire citadel, with its ſix baſtions. Or if you place part of a ball-room, ornamented with chandeliers and figures in enamel, all thoſe objects being here multiplied will afford a very pleaſing proſpect.

RECREATION XVII.

To draw an irregular figure, which ſhall appear regular when viewed in a plane mirror.

DIVIDE the ſquare A B C D (Pl. VII. Fig. 2.) into ſuch number of leſſer ſquares as you ſhall think proper, and then draw on it the ſubject you would repreſent. Make the line GF (Fig. 3.) equal to a ſide of the ſquare A B C D; and after having divided it into two equal parts at the point E, through that point draw the indefinite line A B, which muſt cut the line G F at right angles. Take any two points in the line A B, as A and B, equally diſtant from the point E, and draw from the point A the lines A C and A D, which you muſt continue till they meet the line C D, parallel to G F.

On the point A draw A H perpendicular to A B, and of an equal length with the line

line CD, that is, double of that which forms a side of the square ABCD.

Divide the line CD into as many equal parts as there are in a side of the square ABCD, and from the point A draw the lines A *a*, A *b*. From the point of view H, draw the line H D, which by cutting the lines A *a*, A B, A *b*, will show you the points of the section from which you are to draw the lines *f g*, parallel to G F and C D.

Then transpose on the trapezium, or irregular four-sided figure, GFCD (which will be divided into as many perspective squares as there are natural squares in Fig. 1. A B C D) the design traced on that square; and on the line F G, place perpendicularly a mirror of an equal size with that square. The distorted figure traced on the trapezium GCFD being then viewed in the mirror from a point elevated perpendicularly over the point B, to the height of of CD, will appear exactly ſimilar to that traced on the ſquare ABCD. It will appear equally regular if the mirror be taken away, and it be viewed from the point H.

Note, Before you colour the diſtorted figure drawn on the trapezium, you ſhould paſte it on a board of a parallelogram figure, whoſe ſides are equal to the lines EB and CD; and fill up the ſpace beyond the trapezium with ſuch figures as you ſhall think proper, the better to diſguiſe it: theſe extra figures will not appear in the mirror, if you have the precaution to raiſe at the point B a ſtand that ſhall bear a circle with a ſmall hole, thro' which the object is to be ſeen in the mirror. This contrivance will conſiderably augment the illuſion.

RECREATION XVIII.

The magical dial.

PROCURE a dial-case as ABCD (Pl VII. Fig. 4.) of the size of those that are commonly used to hold a watch. Let it be placed on a pedestal CDEF, in which there must be a small drawer, that can hold the plate ABCD, (Fig. 5.) on which plate draw the circle of hours E, and in the center let there be a magnetic needle, placed on the point of an axis, which, passing through the plate, carries on its other point an artificial magnet, that must be concealed in the part under the plate *.

Place at the bottom of the dial case, at the part F, another dial, the hours of which

* The magnetic needle itself may do, if it be not too far from the other dial. That this needle may not be suspected of having been touched it may be gilt, so as to appear like brass.

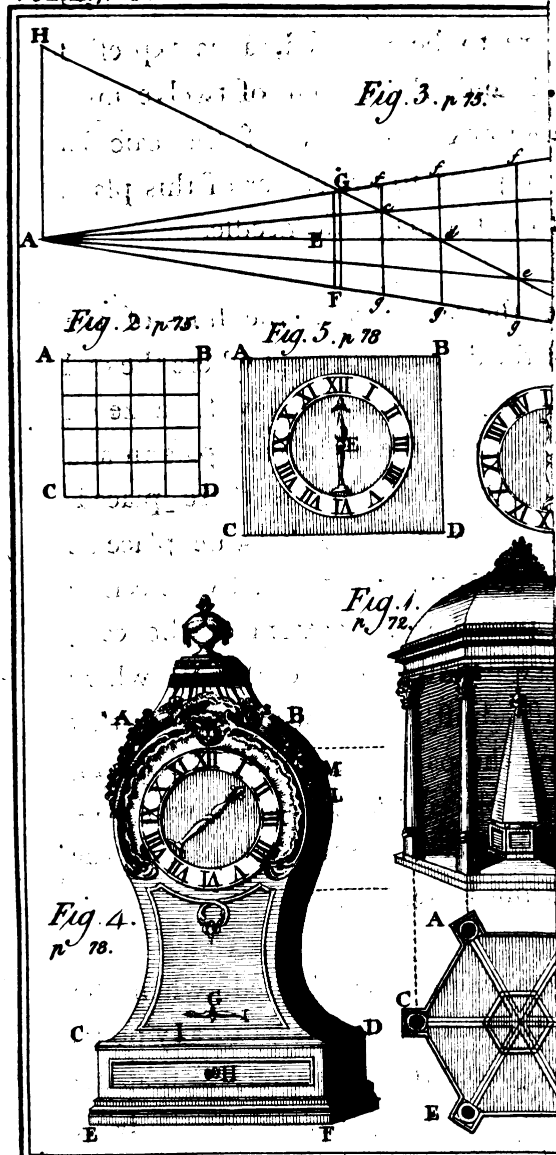


Fig. 3. p 75.
Fig. 2. p 75.
Fig. 5. p 78
Fig. 1. p 72.
Fig. 4. p 78.

which are to be reverſed, as is expreſſed in Fig. 6. and whoſe hour of twelve muſt be placed next the front of the caſe E. Adjuſt a pivot to the center of this plate, and fix on it a magnetic needle.

Cover the openings at the ſides of the front of the dial-caſe (except where the dial appears) with a glaſs, lined with gauze on the inſide, that the light may paſs in and illumine the dial that is there placed. Toward the top of the dial-caſe place an inclined mirror L M, which by reflecting the dial placed at the bottom of the caſe, will make it viſible at the part N, where you muſt adjuſt a circle of paſteboard, that bordering the part where the dial appears, and being placed on the inſide, will prevent the borders or the back part of the mirror from being ſeen.

Matters being thus adjuſted, when the hand of the dial (Fig. 5.) is ſet to any hour, and it is placed in the drawer, ſo that the

hour

hour of twelve may be next the ring by which it is pulled out, the hand of the other dial, placed at the bottom of the caſe, will direct itſelf to the ſame hour, and by looking at the part N, you will ſee, by the reflection of the mirror, the hour appear in the front of the dial plate.

Give the dial (Fig. 5.) to any one, and tell him to ſet the hand, privately, to any hour he pleaſe; and then place it in the drawer, only obſerving that the hour of twelve be next the ring, and he will then ſee that the hand of the dial at top will direct itſelf to the ſame hour.

Note, If attention be had to place the dial-caſe ſo on the table, that the hand of the dial which is concealed (and which will of itſelf turn toward the north, when the other dial is not under it) direct itſelf to the preſent hour when the experiment is making, it will appear the more extraor-

6 nary;

dinary; because, when the drawer is taken away, it will again turn to the present hour, which will render the cause of the illusion still more mysterious.

RECREATION XIX.

The box of divination.

LET a box be made with hinges, like ABCD (Pl. VIII. Fig. 1.) of about eight inches long, two wide, and half an inch thick; divide the inside of it into four equal parts, by small partitions. Have four small cases E, F, G, H, which will each of them fit any of the divisions, and in each of them you must fix a small artificial magnet, whose poles are to be placed as is expressed in the figure. Cover these cases with pasteboard or very thin ivory, on which you are to write any four figures you shall think fit.

To a table I L, whose wood is not too thick, fit a drawer, at the bottom of which muſt be placed an inclined mirror M N, of the ſame length and breadth with the box juſt mentioned. Under the board that forms the top of the table, and toward the ſide where the drawer opens, place a ſmall braſs rod, turned up at its extremities, and on which there muſt be four pivots, at the ſame diſtance from each other as are the centers of the caſes placed in the box. Theſe pivots are to ſupport four circles of paſteboard P Q R S (Fig. 2, and 3.) which muſt each of them have a magnetic needle.

Obſerve, that the figures on the paſte-board muſt not only be reverſed, but muſt be wrote on the under ſide, next the bottom of the drawers, that when it is opened they may be ſeen in the mirror there placed. Have regard alſo to the diſpoſition of the poles of the needles, in the manner as is clearly expreſſed in the third figure.

7 Matters

Matters being thus prepared, when you have placed on the table the box and the four numbers there included, ſo that they may be exactly over the four circles of paſteboard concealed in the drawer, that is, that the centers of the one may be preciſely over the centers of the other, the needles on the circles will conform themſelves exactly to the magnets in the caſes; ſo that, if an inſtant after having placed the box, you open the drawer ſo far as to ſee the mirror, you will there perceive the number that the four figures on the caſes make.

Then give the box and the four caſes to any one, and tell him to form privately any number, by placing the caſes in what order he ſhall think fit, and return you the box firmly cloſed. You then place it on the table over the circles, and opening the drawer, under pretence of taking out an opera glaſs, you caſt your eye on the mirror, and obſerve the order of the figures there expressed. You then shut the drawer, and retiring to a distance, pretend to discern, by the opera glass, the number you have observed.

RECREATION XX.

The magical perspectives.

AT the bottom of an heptagonal or seven-sided box, as A B C D E F G (Pl. VIII. Fig. 4.) of about eight inches diameter, and an inch and a half deep *. Place a circle of pasteboard, of five inches and a half diameter, very light, and moveable, on a pivot fixed in the center H: on this circle fix a strongly magnetic needle I, and divide the circle into 21 equal parts, as is expressed in Fig. 7. The top of the box is to be covered with glass, over which you must paste a sheet of very fine paper, painted the same colour with the box, and

* This box should be so constructed as to appear to be the pedestal to the three perspectives hereafter described.

var-

varnifhed, that the light may eafily pafs through it, and illumine the objects which are to be wrote or painted on the pafte-board circle. On the middle of the top of this box erect a column I, (fee Fig. 5.) fupported on a pedeftal M, and crowned with its capital N.

In the glafs that covers the box there muft be three circular holes, at equal dif-tances from each other, as O, P, Q, each of them three fourths of an inch in dia-meter, and on each muft be fixed, im-moveable, a perfpective glafs, like that in the fixth figure of this plate.

Conftruction of the perfpective glafs.

Provide a ftand of wood A (Fig. 6.) in which a hole is made from top to bottom, of 3-4ths of an inch in diameter; on this ftand place the perfpective B C, which muft have a fecond tube D, like the com-mon glaffes. In the larger part of it F,

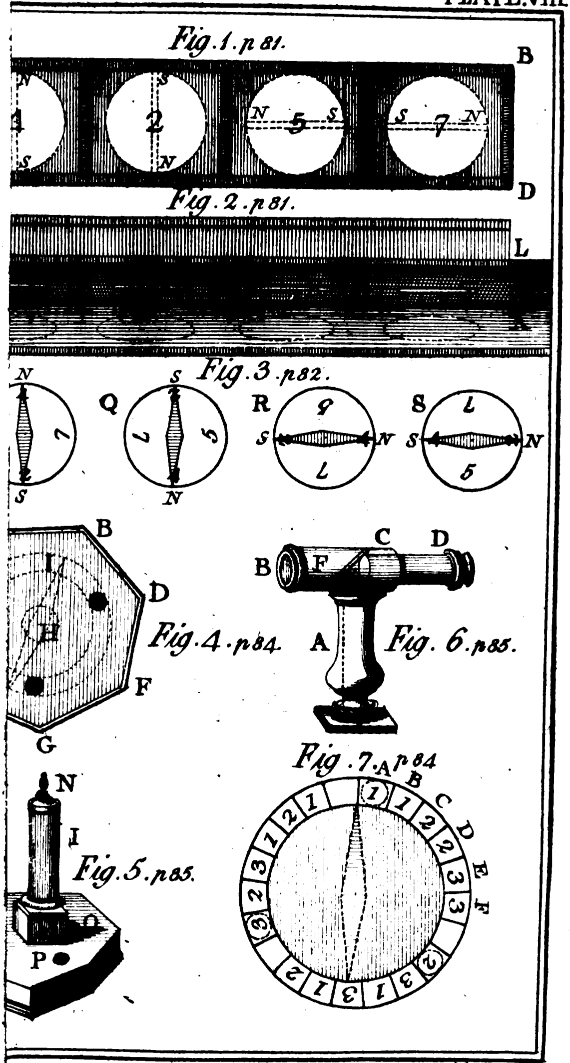
there muſt be a ſmall oval mirror E, which inclines or is elevated as the tube D is thruſt in or drawn out. Let there be a circular hole at that part of the tube which reſts on the ſtand A, that when the mirror is inclined, you may ſee through the ſtand of the perſpective any object that ſhall be placed in the box, under one of the holes O P Q*. Let the three perſpectives ſo conſtructed be placed, immoveable, over thoſe three holes.

The combination of objects that may be drawn on the moveable circle in the box.

This circle is to be divided, as we have ſaid, into 21 equal parts, and each of theſe diviſions muſt appear under each of the openings O, P, Q, as the circle turns round on its pivot.

* At the bottom of the ſtand of each perſpective there may be placed a lens of five or ſix inches in diameter, to magnify the object.

You



J. Lodge Sculp.

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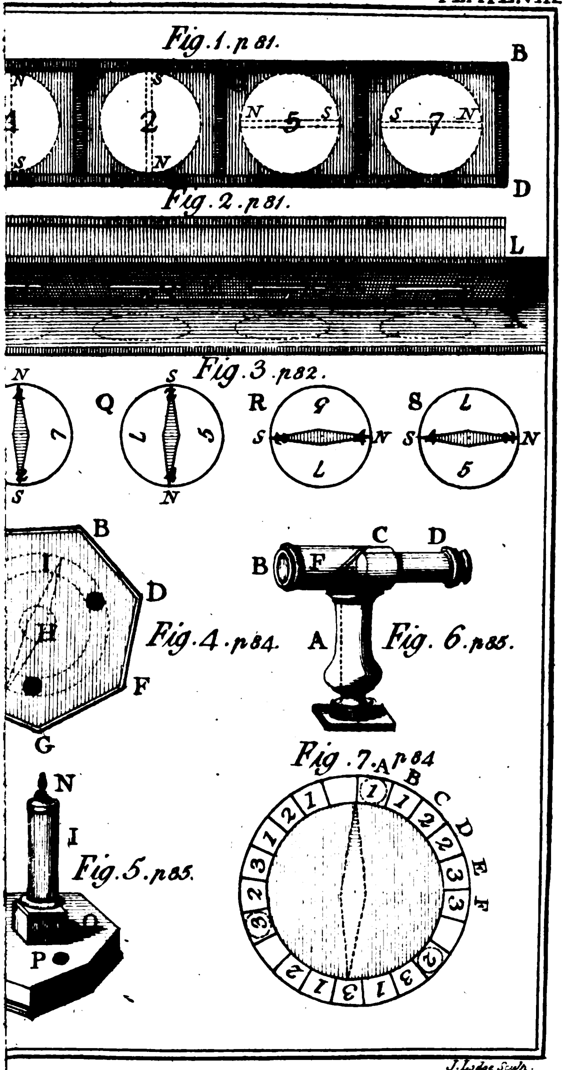


Fig.1.p81.
B
D
Fig.2.p81.
L
Fig.3.p82.
Q
R
S
Fig.4.p84.
Fig.6.p85.
Fig.5.p85.
Fig.7.p84
J.Lodge Sculp.

You are to determine what three objects you would have appear under the three perspectives; and supposing, for example, that they are represented by the numeral figures 1, 2, and 3, you will find that these three figures will admit of six combinations or different dispositions, as

1,2,3. 1,3,2. 2,1,3. 2,3,1. 3,1,2. 3,2,1 *.

Then place the numbers, or the objects they represent, in such order that the first number, 1, of the first combination 1, 2, 3, may be in the first division A, of the circle, (see Fig. 7.) the second number, 2, in the eighth, and the third number, 3, in the fifteenth division: that the first number, 1, of the second combination, may be placed in the second division B; the second number, 3, in the ninth division; and the third number, 2, in the sixteenth division, &c. Having thus filled up eighteen of the divisions with the six combinations of numbers, the other three are to be left blank.

* See vol. I. page 9. aphorism 16.

The circle being thus prepared, is to be placed on its pivot, and to one of the feven fides of the box (Fig. 4.) is to be adjufted a lever or ftop, that being let down on the circle, at pleafure, may prevent it from turning.

When the three perfpectives are placed on the box, and turned toward the column erected on its center, if the fmalleft tube be thruft in, it raifes the mirror that is contained in each of them, and by the hole B the column is feen. If on the contrary the fmall tube be drawn a little way out, the mirror becomes inclined, and you then fee one of the three objects that are placed in the box, under each opening in the ftands of the perfpective, and thefe objects will neceffarily appear in the order of one of the fix combinations of which they are alone fufceptible.

By placing the box on the table, in which a magnetic bar, fix inches long,

long *, muſt be concealed, and whoſe direction you know, you may eaſily make the three objects above mentioned appear oppoſite the three holes O, P, Q, with all their changes; for nothing more is neceſſary than to place the box according to a mark that is on the table, oppoſite to which you are to place one of its ſeven ſides; and by letting down the private check you keep the circle fixed.

The amuſements that are to be made with theſe perſpectives may be varied according to the number of different objects that can be placed on the moveable circle. We ſhall content ourſelves here with giving an example in numbers, which may be applied to any other ſubject, the difference of objects making not the leaſt difference in the manner of performing this Recreation; which, when well executed,

* This bar ſhould be ſtrongly impregnated, that it may readily turn the paſteboard circle.

never

never fails to excite the higheſt admiration.

Firſt then, you are ſo to place the moveable circle, that the three diviſions on which there is nothing wrote may appear under the three holes O, P, Q *, and the ſmall tube of the perſpectives is to be ſo diſpoſed that the mirrors on the inſide may incline to forty-five degrees †, and reflect the objects placed under thoſe holes. The perſpectives being thus diſpoſed, they are placed on the table, and liberty is given thoſe that deſire it, to look into them, as they can then ſee no object. You are then to preſent to three different perſons, three ſuch objects as you ſhall think proper ‡;

* This muſt be done privately, by means of the check, before the machine is brought to the table.

† That is, be half way between a line drawn perpendicular to the ground, and its ſurface.

‡ Theſe objects may be either numbers, flowers, cards, mottos, &c. it is only neceſſary that the circle be properly painted. You may alſo have different circles to vary the Recreation yet farther, by privately changing them.

we

we will suppose here the three numbers 1, 2, 3. When each of the three persons has made choice of one of these numbers, you roll the three cards on which they are wrote, altogether, and put them into the column, opposite to which the three perspectives are placed; and give each person liberty to choose in which glass he will see his object *.

When the three parties have chose their perspectives, the box is to be placed on the table, where the bar is concealed, taking due care to set it in such direction that the openings O, P, Q, may correspond to those parts of the circle on which the objects are wrote. A short time must be given the circle to settle, and then the

* It is immaterial which glass the first person chooses, before the box is placed on the table, but if the second should not name that under which his object is placed, the box must be moved; however, is is an equal chance but he does, and in that case they may all three see their objects at the same time.

check

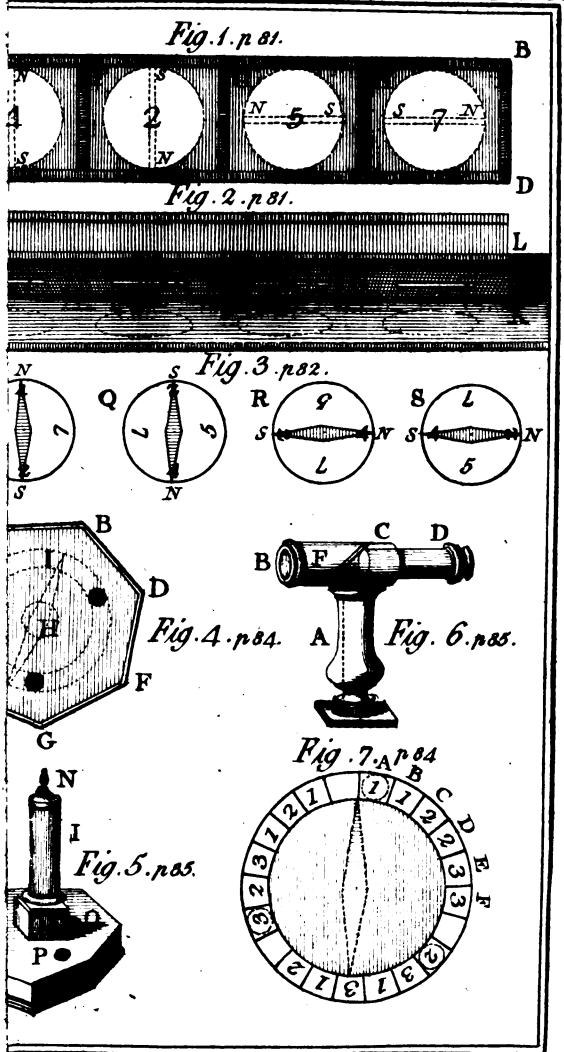
there must be a small oval mirror E, which inclines or is elevated as the tube D is thrust in or drawn out. Let there be a circular hole at that part of the tube which rests on the stand A, that when the mirror is inclined, you may see through the stand of the perspective any object that shall be placed in the box, under one of the holes O P Q*. Let the three perspectives so constructed be placed, immoveable, over those three holes.

The combination of objects that may be drawn on the moveable circle in the box.

This circle is to be divided, as we have said, into 21 equal parts, and each of these divisions must appear under each of the openings O, P, Q, as the circle turns round on its pivot.

* At the bottom of the stand of each perspective there may be placed a lens of five or six inches in diameter, to magnify the object.

You



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* This muſt be done privately, by means of the check, before the machine is brought to the table.

† That is, be half way between a line drawn perpendicular to the ground, and its ſurface.

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When the three parties have chose their perspectives, the box is to be placed on the table, where the bar is concealed, taking due care to set it in such direction that the openings O, P, Q, may correspond to those parts of the circle on which the objects are wrote. A short time must be given the circle to settle, and then the

* It is immaterial which glass the first person chooses, before the box is placed on the table, but if the second should not name that under which his object is placed, the box must be moved; however, is is an equal chance but he does, and in that case they may all three see their objects at the same time.

check

check muſt be privately let down. The three perſons then looking through the perſpective they have each of them choſe, their objects will naturally appear to them in that part of the column where their cards were placed *.

Note, It requires ſome memory to perform this Recreation with facility, as you muſt keep in mind the ſix changes of order, which the liberty you give the ſpectators to ſee through which of the glaſſes they pleaſe, requires. You may, however, to avoid charging your memory, trace on the box certain ſigns, which at the ſame time that they appear to be ornaments, may ſhow you in what direction the box is to be placed.

* You may then propoſe to each of them to make him ſee his object through another perſpective, which you do by removing the check, and putting the box in a different direction.

RECRE-

RECREATION XXI.

The penetrating perſpective.

WITHIN the caſe ABCD, (Plate X. Fig. 1.) place four mirrors, O, P, Q, R, ſo diſpoſed that they may each of them make an angle of forty-five degrees, that is, that they may be half way inclined from the perpendicular, as in the figure. In each of the two extremities AB, make a circular overture, in one of which fix the tube GL, in the other the tube MF, and obſerve that in each of theſe is to be inſerted another tube, as H and I *.

Furniſh the firſt of theſe tubes with an object-glaſs at G, and a concave eye-glaſs at F. You are to obſerve, that in regulating the focus of theſe glaſſes, with regard to the length of the tube, you are to ſup-

* Theſe four tubes muſt terminate in the ſubſtance of the caſe, and not enter the inſide, that they may not hinder the effect of the mirrors.

poſe

Note, This Recreation is the more extraordinary, as it is very difficult to conceive how the effect is produced. The two arms of the case appearing to be made to support the perspective glass; and to whatever object it is directed, the effect is still the same.

RECREATION XXII.

The magician's mirrors.

IN the partition AB, (Plate X. Fig. 2.) make two overtures, CD, and EF, of a foot high, and ten inches wide, and about a foot distant from each other. Let them be at the common height of a man's head; and in each of them place a transparent glass, surrounded with a frame, like a common mirror.

Behind this partition place two mirrors H and I, inclined to it in an angle of forty-five degrees *: let them be both eighteen inches square: let all the space be-

* See page 90.

tween,

tween them be enclosed by boards or pasteboard, painted black, and well closed, that no light may enter: let there be also two curtains to cover them, which may be drawn aside at pleasure.

When a person looks into one of these supposed mirrors, instead of seeing his own face, he will perceive the object that is in front of the other; so that if two persons present themselves at the same time before these mirrors, instead of each one seeing himself, they will reciprocally see each other.

Note, There should be a sconce with a candle placed on each side of the two glasses in the wainscot, to enlighten the faces of the persons who look in them, otherwise this experiment will have no remarkable effect.

This Recreation may be considerably improved by placing the two glasses in the

 partition,

partition, in adjoining rooms, and a number of perſons being previouſly placed in one room, when a ſtranger enters the other, you may tell him his face is dirty, and deſire him to look in the glaſs, which he will naturally do; and on ſeeing a ſtrange face he will draw back: but returning to it, and ſeeing another, another, and another, like the phantom kings in Macbeth, what his ſurprize will be is more eaſy to conceive than expreſs. After this, a real mirror may be privately let down on the back of the glaſs, and if he can be prevailed to look in it once more, he will then, to his further aſtoniſhment, ſee his own face; and may be told, perhaps perſuaded, that all he thought he ſaw before was mere imagination.

How many tricks leſs artful than this, have paſſed in former times for ſorcery; and paſs at this time, in ſome countries, for apparitions?

Note, When a man looks in a mirror that is placed perpendicular to another, his face

face will appear entirely deformed. If the mirror be a little inclined, ſo as to make an angle of eighty degrees (that is one ninth part from the perpendicular) he will then ſee all the parts of his face except the noſe and forehead. If it be inclined to ſixty degrees (that is, one third part) he will appear with three noſes and ſix eyes: in ſhort, the apparent deformity will vary at each degree of inclination; and when the glaſs comes to forty-five degrees, (that is, half way down) the face will vaniſh. If inſtead of placing the two mirrors in this ſituation, they are ſo diſpoſed that their junction may be vertical, their different inclinations will produce other effects; as the ſituation of the object relative to theſe mirrors is quite different. The effects of theſe mirrors, though remarkable enough, occaſions but little ſurprize, as there is no method of concealing the cauſe by which they are produced.

RECREATION XXIII.

Polemoſcopes.

BY the term polemoſcope is meant any inſtrument, whether catoptric or dioptric, by which you may ſee what paſſes in another place, without being ſeen from thence. Theſe machines contain one or more plane mirrors, which convey by reflection the image of the object to the eye of the ſpectator. There are ſmall inſtruments of this kind, made in the form of an opera-glaſs, by which, while you ſeem to look ſtrait forward, you ſee what paſſes on one ſide, and by that mean gratify your curioſity without the appearance of incivility.

To the conſtructing of this ſort of polemoſcope nothing more is neceſſary than to fix in a common opera glaſs a ſmall mirror, inclined to an angle of forty-five degrees, and adjuſt a proper object-glaſs. This glaſs at the ſame time may anſwer its

its common use, by adding an object-glass, and so contriving the small tube that it may remove the mirror at pleasure, as in the 21st Recreation.

The tube of a polemoscope may be placed against a wall, the inclined mirror being a little above it, and turned outwards, by which mean you will discover what passes on the other side, without being seen yourself. An instrument of this sort would be of use in sieges, where there is danger without the wall from the fire of the enemy; and on other occasions. This instrument may be also so constructed, that the tube may turn round, and the mirror be elevated or depressed, that you may see successively and at pleasure, all the objects that you would perceive if you were at the top of the wall against which the instrument is placed.

RECREATION XXIV.

The enchanted mirrors.

MAKE a box of wood, of a cubical figure, ACBD, (Plate X. Fig. 3) of about fifteen inches every way. Let it be fixed on the pedeſtal P, at the uſual height of a man's head. In each ſide of this box let there be an opening of an oval form, of ten inches high, and ſeven wide.

In this box place two mirrors A, D, with their backs againſt each other; let them croſs the box in a diagonal line, and in a vertical poſition. Decorate the openings in the ſides of this box with four oval frames and tranſparent glaſſes, and cover each of them with a curtain, ſo contrived that they may all draw up together.

Place four perſons in front of the four ſides, and at equal diſtances from the box, and then draw up the curtains that they

they may see themselves in the mirrors; when each of them, instead of his own figure, will see that of the person who is next him, and who, at the same time, will seem to him to be placed on the opposite side. Their confusion will be the greater, as it will be very difficult for them to discover the mirrors concealed in the box. The reason of this phenomenon is evident, for though the rays of light may be turned aside by a mirror, yet, as we have before said, they always appear to proceed in right lines.

RECREATION XXV.

The animated optic balls, (by a single reflection.)

THIS piece of catoptrics, as well as that which follows of double reflection, being of the class that produces the most pleasing illusion, we shall here give a full detail of the manner in which it is to be executed.

Provide a wooden box ABCD, of about two feet high, and fifteen inches wide (Plate IX. Fig. 1.) and toward the top let there be made an opening E, of eight or nine inches high, and seven or eight inches wide, and in this opening fix a transparent glass *. Let the box be two feet deep (see the profile ABCD, Fig. 2.) and adjust to it a partition ST, of the same width, and that is fifteen inches deep from S to T; observe, that this partition will separate the box into two divisions, the upper of which must be one or two inches less than the under.

In the upper division, and toward the extremity S of the partition ST, and cross it, place a small decoration KS, of the figure of the outward scene of a theatre, in which let there be an opening of ten inches wide, and eight inches high.

* If the dimensions of the box be larger, the exhibition will be more perfect; and on the contrary, if it be smaller, it will be less perfect.

Behind

Behind this scene place the mirror K F, (Fig. 2.) in an angle of forty-five degrees, as in the common optical machines, and observe that it be of the same width with the box, and large enough to cover the overture of the front scene, when the eye is placed at the transparent glass E.

Decorate the interior space K S B T, with such different paintings as you shall judge will contribute most to the pleasure of the exhibition. Cover the top of the box, from K to B, with a frame in which is a glass lined with gauze, that the light may enter the part K S B T. This first construction being made, in the proportions and with the precautions here laid down, you are next to place the inclined plane, hereafter described, which must be of a size to enter this edifice by a back door made at G H.

Construction of the inclined plane.

This plane should incline to the base of the structure in an angle of about thirty degrees, *Construction of the wheel for remounting the balls incessantly.*

In the center of the toothed wheel A, (Plate IX. Fig. 5.) place a barrel with a ſpring, and let it be alſo in the center of the braſs rod FG. The pinion of the wheel B is to take the teeth of the firſt wheel A; and its teeth are to turn the fly C, whoſe wings muſt be moveable, that by being more or leſs inclined, they may accelerate or retard the motion of the machine.

To the wheel A let there be fixed two braſs rods *, and at the extremity of each there muſt be a box D, (ſee the profile Fig. 6. Plate X.) whoſe overture MN is cloſed by a valve H, that moves freely on the point I: the axis of this valve muſt come out beyond the ſurface of the box, that the check L may be there placed, which

* The axis of this wheel ſhould project, that it may be wound up by a key, in the ſame manner as a clock.

ſhould

ſhould move freely, and at the ſame time with the valve. Theſe boxes muſt be large enough to contain, each of them, one of the balls, that are, as we have ſaid, to roll on the inclined plane, (Fig. 2.); and that it may enter at the ſide M of the valve, which muſt then cloſe. The ſides of theſe boxes muſt incline, as in Fig. 5. Plate X.

Obſerve alſo, that this wheel muſt be of a proper ſize to place at the back of this machine, near that part where the inclined plane is placed, (ſee Fig. 4. Plate IX.) that it may not only receive in its revolving boxes the balls, that after having rolled on the plane, paſs out by the groove O P, (Fig. 2.) but may alſo raiſe them again to the height C, (Fig. 4.) where there ſhould be a ſmall channel to receive and conduct them to the top of the inclined plane. Remark alſo, that toward the part M there muſt be a little iron catch, that may ſucceſſively ſtop the checks L, which are fixed to the axis of the valves, that it may

may give time to the ball to paſs into the box at the part M, and diſcharge the check L: in like manner when the box comes to the height of the groove that is to conduct the ball to the inclined plane, there muſt be another catch to open the valve and diſcharge the ball.

The wheel being thus placed, at the back of the machine, and the ſpring wound up, the balls will inceſſantly deſcend and remount till the ſpring in the box at the axis of the wheel is quite unbent *.

When a ball is put into the groove at the top, and runs down the inclined plane, he that looks into the glaſs placed in front of the box, will imagine that it aſcends by various turnings, and goes out at the top of the edifice. The appearance will become the more pleaſing as the different

* There ſhould be a caſe over this wheel, with a door to open, that the contrivance may be quite free from detection.

windings

windings of the ball are properly adapted to the subject painted on the inclined plane. This piece, when executed with care, produces a very remarkable illusion, and is one of the most pleasing Recreations of catoptrics.

RECREATION XXVI.

The same exhibition by a double reflection.

THIS differs from the foregoing by having a mirror inclined in an angle of forty-five degrees, (see Plate IX. Fig. 2.) in the room of the inclined plane, and by having the plane on which the balls roll placed near the part of the box TD.

There may be placed, moreover, toward ST, and in a position almost horizontal, little columns, arbours, or other objects, made of brass wire, at equal distances *,

* This wire should have a small inclination, which may be two tenths of an inch for every foot; and the distance between the wires should be something less than the diameter of the balls.

and

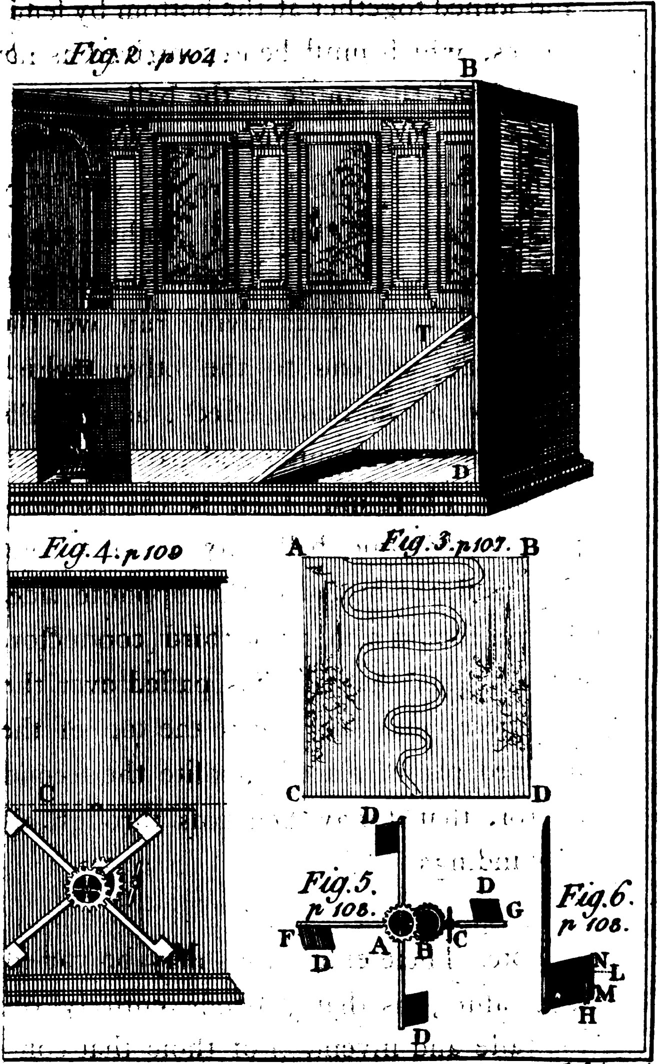
and joined together at the bottom by ſemi-circles, which muſt be ſo contrived as not to obſtruct the courſe of the ball.

If there be ſufficient room, you may place, under the former, another range of wires, that have a ſimilar diſpoſition, ſo that the ball, after having run over the firſt, may deſcend to the other, which will have a remarkable effect; as the balls will ſeem to rencounter and paſs over each other. There muſt then be two conductors, ſo that one ball may enter at one ſide, and the other at the oppoſite ſide. There ſhould alſo be a third conductor, which, after the ball has paſſed over the firſt piece, may carry it to the top of the inclined plane, placed oppoſite the ſecond mirror, that it may then paſs through all its windings.

Note. Theſe exhibitions may be varied at pleaſure, as that depends entirely on the taſte and invention of thoſe that con-

ſtruct

PLATE IX.



J. Lodge sculp.

ſtruct them. You ſhould obſerve to give but a very ſmall inclination to the grooves in which the balls run. Theſe balls may be of ivory painted, as thoſe of braſs make too much noiſe in the box, and are ſubject to break the inclined mirror, when by chance they jump out of the groove and fall on it.

The grooves ſhould be concealed as much as poſſible by paintings or ornaments. They ſhould be either of braſs, tin, or thin paſteboard. In a word, too much care cannot be taken in conducting exhibitions of this nature.

RECREATION XXVII.

To describe on a plain surface an irregular figure, which shall appear regular when placed opposite a multiplying glass, and seen by reflection through an aperture made in the center of the drawing.

WE shall not here lay down the geometric manner of drawing this figure, for it would not only be very complicate, and extremely difficult to execute, but when done could not succeed, on account of the impossibility of procuring glasses of this sort, whose planes are equally inclined and perfectly regular.

CONSTRUCTION.

Procure of an able artist a mirror of metal (Plate X. Fig. 4.) whose base is a hexagon of about two inches and a half in diameter, and about half an inch thick at its center. Let the faces of this mirror be very truly cut, their angles very sharp, and

and their ſurfaces highly poliſhed. Cement this mirror to a ſtand of about half an inch thick, and let it be firmly joined by means of a ſcrew, at the point A, (Fig. 5.) which ſhould be eight or nine inches high; and let the ſtand be ſolidly fixed on the top of the box B C*.

At the end C of this box (Fig. 5.) place an upright frame with a groove, which is to remain there, and in which are to be placed the deſigns, of about fifteen inches ſquare, containing the different diſtorted figures that are to appear regular, when ſeen in the glaſs, which, as appears by the figure, will then be oppoſite to it.

In the center of the drawing make a hole of about three tenths of an inch in diameter, through which the mirror may be entirely ſeen, and which ſhould be placed

* This box may have a drawer, to contain the different paintings that are to be ſeen by the mirror: it may be eight or nine inches wide, and fifteen inches deep.

exactly oppoſite that hole, with its baſe parallel to the drawing or picture.

Draw on a paper or paſteboard the geometric plan of the multiplying glaſs, (ſee Fig. 7.) and on that draw the deſign you would have ſeen in the mirror. Theſe preparations being made with great attention, that is, the mirror being properly fixed, and the drawing rightly adjuſted, look at the mirror through the hole H, made in the drawing, and holding the ruler AB *, by its handle D, (ſee Fig. 6.) in your left hand, move it in different directions over the drawing till its ſide C appear to the eye (remaining conſtantly at H) to be exactly even with one of the ſides of the glaſs; there keep it fixed; and taking the eye from the hole, draw with a black lead pencil, that you have ready in the other hand, a line by the

* This ruler ſhould be about three or four inches long, very thin and black. It may be made of part of the ſpring of a clock.

ruler.

ruler. Do the ſame by the other ſides of that face of the glaſs, and then the ſpace contained between thoſe two lines will be that on which you are to tranſpoſe that part of the deſign which is drawn on the correſponding face in Fig. 4.

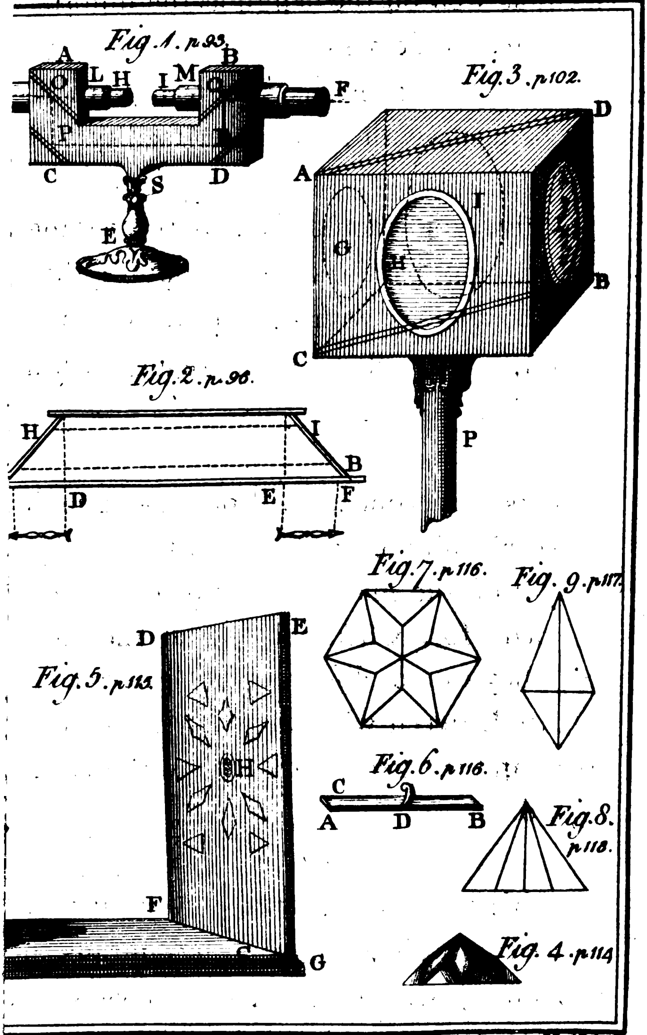
Do the ſame by all the other faces of the glaſs, and you will then have twelve faces that will correſpond to thoſe of the mirror, and which altogether muſt conſequently contain the entire ſubject that is traced on Fig. 7.

Theſe ſpaces not differing much from thoſe of the mirror, it will be eaſy to trace the object that has been deſigned; it will be only neceſſary to number them, to prevent any miſtake; and to place the paper or paſteboard before the mirror, after you have lightly traced the deſign; and inſpect it by the hole H, that you may diſcover and rectify any errors that may have been made. Theſe ſpaces may alſo be ſubdivided, as well on the design as the distorted figure, in the manner expressed in Fig. 8, and by that means the transposition will be made with still greater facility.

Lastly, you should fill up the vacant parts on the pasteboard with figures that have no analogy with those in the original design, and by that means render it still more surprising,

This experiment will produce a most agreeable illusion to those who are ignorant of the manner in which it is performed: for, when looking at the point H, they cannot discover the least resemblance between what they see in the mirror, and the general design on the pasteboard.

Observe, this drawing may also be traced correctly enough by means of a lamp, placed at the point of view H, taking care to enclose it in a tin case, and



J. Lodge sculp.

to adjuſt to it a tube of about an inch in diameter, and three or four inches long, that can be protracted or ſhortened at pleaſure. When you uſe this method, a hole muſt be made in the paper, large e-nough to admit the end of the tube; ſo that the light falling on the ſeveral faces of the glaſs, they may be reflected on the paper, and ſhow where each of them is to be traced. By this method the time ſpent in finding them by the ruler is ſaved; and if the light be ſteady, the drawing will anſwer very well. You may alſo draw on the mirror, with ſoot, tempered with fine white lead, all the ſtrokes of the deſign, and by that means ſtill ſhorten the execution of the drawing.

RECREATION XXVIII.

To describe on a plane surface a deformed figure, which shall appear regular when viewed by reflection in a cylindrical mirror.

THE geometric method of describing this irregular figure, being, as in the last Recreation, not only extremely difficult, on account of its different curves, but also liable to error from the want of regularity in making the mirrors; we shall here shew another method of describing it, far less learned indeed, but much more concise, and easily practicable by those who have not a profound knowledge of geometry, but are yet desirous of drawing these sorts of anamorphoses.

Let ABCD be the cylindrical mirror *, (Plate XI. Fig. 1.) in which you would see,

* Fig. 6. Plate XI. represents the projection of the cylindric mirror, drawn on paper.

 from

from the point of view E, the deformed object painted on the board FG in a regular form.

On a paper, or pasteboard, draw the circle A (Fig. 2.) equal to the base BD of the cylindric mirror; and taking the point B for the distance of the point of view from the mirror, draw the line AB, which must pass through A, the center of the circle. Then draw the two lines BC and BD.

Divide the line CD into six equal parts, and draw from the point of view B, the lines B *i*, which by cutting one of the sides of the circle, will determine the points on which you are to erect the parallel perpendiculars, which may be done by a ruler; making use of an opaque colour that will effectually obscure those parts of the cylinder where they are drawn *.

* You may use soot and white lead ground together with gum, after having traced the lines with a crayon.

These

These first divisions being regularly made, divide about two thirds of the height of the side CD, of the cylinder, into ten or twelve parts, respectively equal to those of the diameter of the circle (Fig. 7.) and from the point of view E, draw the lines E*l*, which passing through all the points of division, must be continued to the other side of the cylinder. On the two opposite sides of the cylinder mark the different heights of the several divisions, and thro' those points draw the oval figures *il*, making use of the same colour as before.

Take a paper ABCD (Fig. 3.) whose two sides AB and CD must be divided into six equal parts, and those of AC and BD into ten or twelve equal parts, on which you are to draw the figure as you would have it appear to the eye when viewed in the cylindric mirror. At the point of view E, place a lamp, so disposed that its light may fall on the cylindric mirror only.

When you have fixed the cylinder on the pasteboard F G (Fig. 6.) and the lamp is placed at E, so that its light cannot fall on the pasteboard, but by reflection, all the strokes on the cylinder will then appear on the board, and may be easily traced with a pencil. By this means the board will be divided into as many irregular spaces, as there are regular divisions in the parallelogram (Fig. 8.) If, therefore, you transfer to each of those spaces the strokes of the design that is on the parallelogram, it will appear quite deformed on the pasteboard, and quite regular when seen from the point of view E, especially if due attention be had to drawing the outlines of the figure.

Note, The point of view should be four or five inches above the upper part of the mirror, that you may not be obliged to make use of a very large pasteboard: it should not, however, be much higher, as then the figure on the board would not be sufficiently deformed.

By

By this method you may alſo draw irregular figures to be ſeen in a priſm, or any other ſort of mirror, provided they can be traced and illuminated *.

Obſerve, if you are deſirous of painting theſe ſorts of anamorphoſes to advantage, you muſt not overcharge thoſe parts with colour that are moſt diſtended, for when they become contracted in the mirror the colours appear unnatural. In a word, great attention is neceſſary in drawing and painting theſe ſubjects, as on that the ſucceſs principally depends.

* The geometric method of drawing deformed objects to be ſeen in a priſm, will be found at large in the treatiſe of Abbé Nollet.

RECRE-

RECREATION XXIX.

Optical appearances.

OF all our ſenſes the ſight is certainly ſubject to the greateſt illuſion. The various writers on optics have deſcribed a great number of inſtances, in which it deceives us, and have conſtantly endeavoured to inveſtigate the cauſes, to explain their effects, and to reconcile appearance with reality. We every day diſcover new phenomena, and doubtleſs many more are reſerved for poſterity. It frequently happens, moreover, that a diſcovery which at firſt ſeemed of little conſequence, has led to matters of the higheſt importance.

Take a glaſs bottle A, (Pl. XII. Fig. 4.) and fill it with water to the point B; leave the upper part B C, empty, and cork it in the common manner. Place this bottle oppoſite a concave mirror, and beyond its focus, that it may appear reverſed, and be-

fore

fore the mirror (see aphorism 4. page 65.) Place yourself still further distant than the bottle, and it will appear to you in the situation *a*, *b*, *c*, (Fig. 5.)

Now it is remarkable in this apparent bottle, that the water, which, according to all the laws of catoptrics, and all the experiments made on other objects, should appear at *a b*, appears on the contrary at *b c*, and consequently the part *a b* appears empty.

If the bottle be inverted and placed before the mirror (as in Fig. 6.) its image will appear in its natural, erect position; and the water, which is in reality at B C, will appear at *a b*.

If while the bottle is inverted it be uncorked, and the water run gently out, it will appear that while the part B C is emptying, that of *a b* in the image is filling; and what is likewise very remark-able,

PLATE XI.

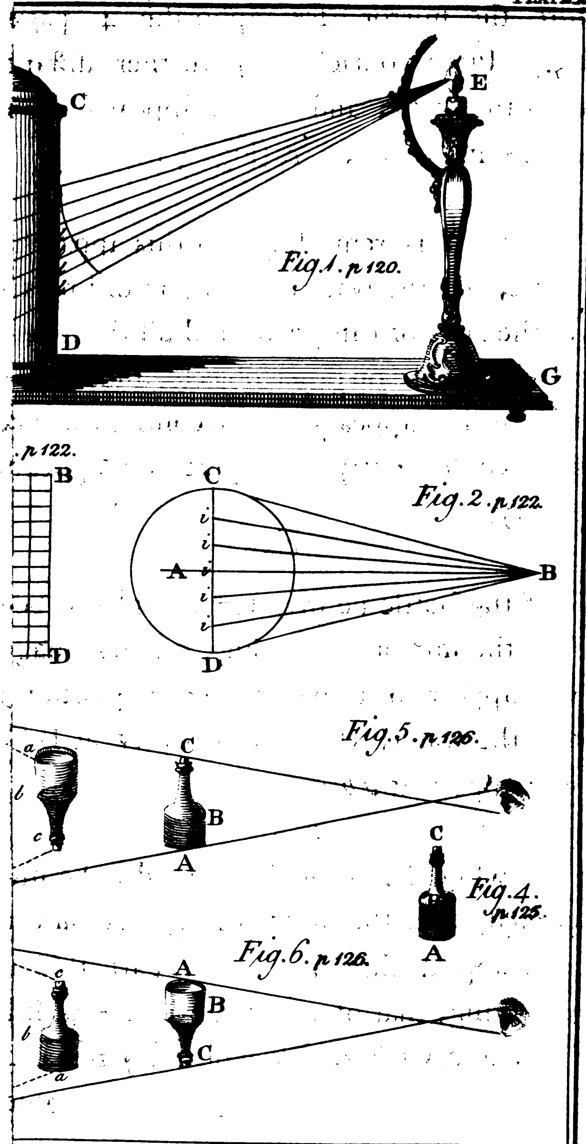


Fig. 1. p. 120.

p. 122.

Fig. 2. p. 122.

Fig. 5. p. 126.

Fig. 4. p. 125.

Fig. 6. p. 126.

J. Lodge Sculp.

able, as ſoon as the bottle is empty the illuſion ceaſes, the image alſo appearing entirely empty. If the bottle likewiſe be quite full there is no illuſion.

If while the bottle is held inverted, and partly empty, ſome drops of water fall from the bottom A towards B C, it ſeems in the image as if there were formed at the bottom of the part *a b*, bubbles of air that roſe from *a* to *b*; which is the part that ſeems full of water. All theſe phenomena conſtantly appear.

The remarkable circumſtances in this experiment, are, firſt, not only to ſee an object where it is not, but alſo where its image is not; and ſecondly, that of two objects which are really in the ſame place, as the ſurface of the bottle and the water it contains, the one is ſeen at one place, and the other at another; and to ſee the bottle in the place of its image, and the water where neither it, nor its image, are.

Note,

Note, It has been conjectured, with ſome appearance of reaſon, that this illuſion ariſes partly from our not being accuſtomed to ſee water ſuſpended in a bottle with the neck downward, and partly from the reſemblance there is between the colour of the air and that of water, which induces us to imagine that we ſee them where they uſually are; and this is rendered more probable by putting any coloured liquor into the bottle, for that will appear in its proper place (M. Guyot.)

RECREATION XXX.

The perſpective mirror.

PROVIDE a box ABCD (Pl. XII. Fig. 1.) of about two feet long, fifteen inches wide, and twelve inches high. At the end AC place a concave mirror, the focus of whoſe parallel rays is at eighteen inches from the reflecting ſurface. At IL place a paſteboard blacked, in which a hole a hole is cut sufficiently large to see on the mirror H, the object placed at B E F D.

Cover the top of the box, from A to I, close, that the mirror H, may be entirely darkened. The other part I B, must be covered with a glass, under which is placed a gauze.

Make an aperture at G, near the top of the side E B; beneath which, on the inside, place, in succession, paintings of different subjects, as vistas, landscapes, &c. so that they may be in front of the mirror H. Let the box be so placed that the object may be strongly illumined by the sun; or by wax lights placed under the enclosed part of the box A I.

By this simple construction the objects placed at G D will be thrown into their natural perspective, and if the subjects be properly chose, the appearance will be altogether as pleasing as in optical machines of a much more complicated form.

Note, A glaſs mirror ſhould be always here uſed, as thoſe of metal do not repreſent the objects with equal vivacity, and are beſide ſubject to tarniſh. It is alſo neceſſary that the box be ſufficiently large, that you may not be obliged to uſe a mirror whoſe focus is too ſhort; for in that caſe, the right lines near the border of the picture will appear bent in the mirror, which will have a diſagreeable effect, and cannot be avoided.

RECREATION XXXI.

To ſet fire to a combuſtible body, by the reflection of two concave mirrors.

THE rays of a luminous body placed in the focus of a concave mirror being reflected in parallel lines, if a ſecond mirror be placed diametrically oppoſite the firſt, it will, by collecting thoſe rays in its focus, ſet fire to a combuſtible body.

Place two concave mirrors, A and B (Pl. XII. Fig. 2.) at about twelve or fifteen feet

feet diſtance from each other, and let the axis of each of them be in the ſame line. In the focus C, of one of them, place a live coal, and in the focus D of the other, ſome gunpowder. With a pair of double bellows, which make a continual blaſt, keep conſtantly blowing the coal, and notwithſtanding the diſtance between them the powder will preſently take fire.

It is not neceſſary that theſe mirrors be of metal or glaſs; thoſe made of wood or paſteboard, gilded, will produce the exploſion, which has ſometimes taken effect at the diſtance of fifty feet, when mirrors of eighteen inches or two feet diameter have been uſed.

This experiment ſucceeds with more difficulty at great diſtances; which may proceed from the moiſture in a large quantity of air. It would doubtleſs take effect more readily, if a tin tube, of an equal diameter with the mirrors, were to be placed between them.

RECREATION XXXII.

The real apparition.

BEHIND the partition AB (Pl. XII. Fig. 3.) place, in a poſition ſomething oblique, the concave mirror EF, which muſt be at leaſt ten inches in diameter, and its diſtance from the partition equal to three-fourths of the diſtance of its center.

In the partition make an opening of ſeven or eight inches, either ſquare or circular: it muſt face the mirror; and be of the ſame height with it. Behind this partition place a ſtrong light, ſo diſpoſed that it may not be ſeen at the opening, and may illumine an object placed at C, without throwing any light on the mirror.

Beneath the aperture in the partition place the object C, that you intend ſhall appear on the outſide of the partition, in an inverted poſition; and which we will

ſuppoſe

ſuppoſe to be a flower. Before the partition, and beneath the aperture, place a little flower-pot D, the top of which ſhould be even with the bottom of the aperture, that the eye, placed at G, may ſee the flower in the ſame poſition as if its ſtalk came out of the pot.

Take care to paint the ſpace between the back part of the partition and the mirror black, to prevent any reflections of light from being thrown on the mirror; in a word, ſo diſpoſe the whole that it may be as little enlightened as poſſible.

When a perſon is placed at the point G, he will perceive the flower that is behind the partition, at the top of the pot at D, but on putting out his hand to pluck it, he will find that he attempts to graſp a ſhadow.

Obſervation.

The phenomena that may be produced by means of concave mirrors are highly curious

curious and astonishing. By their aid spectres of various kinds may be exhibited. Suppose, for example, you were to tell any one, that at such an hour, and in such a place, he should see the apparition of an absent or deceased friend (of whose portrait you are in possession). In order to produce this phantom, instead of the hole in the partition A B, in the last figure, there must be a door, which opens into an apartment to which there is a considerable descent. Under that door you are to place the portrait, which must be inverted and strongly illuminated, that it may be lively reflected by the mirror, which must be large and well polished. Then having introduced the incredulous spectator at another door, and placed him in the proper point of view, you suddenly throw open the door at A B, when, to his great astonishment, he will immediately see the apparition of his friend.

It will be objected, perhaps, that this is not a perfect apparition, because it is only

Fig. 1. p 128.

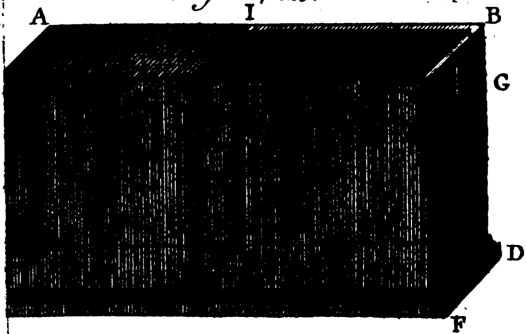
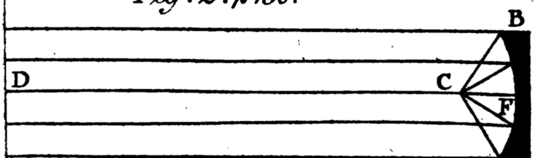


Fig. 2. p 130.



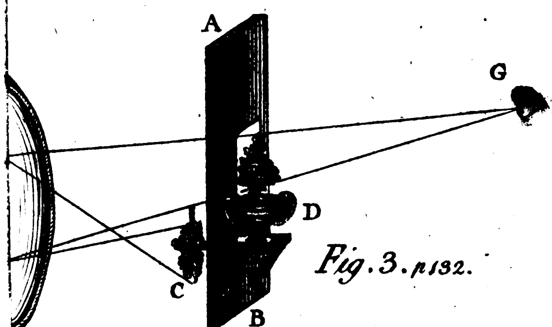


Fig. 3. p 132.

J. Lodge Sculp.

at one point of view, and by one person. But it should be remembered, that it was an established maxim in the last centuries, that a spectre might be visible to one person and not to others. So Shakespeare makes both Hamlet and Macbeth see apparitions that were not visible to others, present at the same time. It is not unlikely, moreover, that this maxim took its rise from certain apparitions of this kind that were raised by the monks, to serve some purposes they called religious; as they alone were in possession of what little learning there then was in the world.

Nothing here said is intended to invalidate the belief that separate spirits may hold converse with men. He must be either very weak or very wicked, who can wish to disbelieve an opinion that is so highly honourable and advantageous to humanity.

There is one phenomenon we must not here omit; for tho' it be common enough, it is alſo pleaſing, and eaſy to be performed. If you place yourſelf before a concave mirror, and at a proper diſtance, your figure will appear inverted, and if you ſtretch out your hand toward the mirror, you will perceive another hand that ſeems to meet and join it, though imperceptible to the touch. If inſtead of your hand you make uſe of a drawn ſword, and preſent it in ſuch manner that its point may be directed toward the focus of the parallel rays of the mirror, another ſword will appear, and ſeem to encounter that in your hand. You are to obſerve, that to make this experiment ſucceed well, you muſt have a mirror of at leaſt a foot in diameter, that you may ſee yourſelf in part. If you have a mirror large enough to ſee your whole perſon, the illuſion will be much more ſtriking. This phenomenon, with which ſo much parade has been made by ſome modern experimental philoſophers, was deſcribed by Baptiſta Porta more than 200 years ſince.

CHRO-

CHROMATICS.

CHROMATICS is that part of optics which explains the ſeveral properties of the colours of light, and of natural bodies.

DEFINITIONS.

1. Thoſe rays of light that are all equally refrangible, are called ſimple or homogenial rays.

2. Thoſe rays that have different degrees of refrangibility, are called compound, or heterogenial *.

3. The colours of homogenial light are called primary or ſimple colours: and

4. Thoſe of heterogeneal light, ſecondary or compound colours.

5. A ſpectrum is a coloured image of the ſun, produced by the refraction of a ray of light let into a dark chamber.

* The terms homogeneal and heterogeneal are derived from the Greek words *omos*, *the ſame*; *eteros*, *another*; and *genos*, *kind* or *ſpecies*.

6. A

6. A prism is a glass body, whose two ends are similar and parallel triangles, and its three sides regular planes.

APHORISMS.

1. All the colours in nature proceed from the rays of light.

2. There are seven primary colours, which are red, orange, yellow, green, blue, indigo, and violet.

3. Every ray of light may be separated into the seven primary colours.

4. The rays of light in passing through the same medium have different degrees of refrangibility.

5. The difference in the colours of light arises from its different refrangibility, that which is the least refrangible producing red, and that which is the most refrangible, violet *.

* It is conjectured that the different refrangibility in the rays of light proceeds from their different magnitude: those of red light, being the largest, make

6. By compounding any two of the primary colours, as red and yellow, or yellow and blue, the intermediate colour, as orange or green, may be produced.

7. The colours of bodies arife from their difpofitions to reflect one fort of rays, and to abforb the other. Thofe that reflect the leaft refrangible rays appearing red; and thofe that reflect the moft refrangible, violet *.

make the strongeft impreffion on the retina; and thofe of violet, being the fmalleft, make the weakeft impreffion.

* It appears highly probable, from obfervations made by Sir Ifaac Newton, that the difpofition of bodies to reflect the different rays of light, arifes from the different fize of their particles. Thus, the azure colour of the fky, and the moft luminous white, as that of metals, he fuppofes to be produced by particles of the firft order; but if the white be lefs intenfe, as that of linen, paper, and fuch like fubftances, he conjectures that it arifes from a mixture of particles of all orders. The green of vegetables he fuppofes to proceed from the third order, and the particles that caufe blacknefs, to be fmaller than thofe that produce any of the colours.

8. Such

8. Such bodies as reflect two or more ſorts of rays, appear of various colours.

9. The whiteneſs of bodies ariſes from their diſpoſition to reflect all the rays of light promiſcuouſly.

10. The blackneſs of bodies proceeds from their incapacity to reflect any of the rays of light *.

RECREATION XXXIII.

Out of a ſingle colourleſs ray of light to produce ſeven other rays, which ſhall paint, on a white body, the ſeven primary colours of nature.

PROCURE of an optician a large glaſs priſm D E F, (Plate XIII. Fig. 1.) well poliſhed, two of whoſe ſides muſt contain an angle of about ſixty-four degrees. Make a room quite dark, and in the window ſhutter A B, cut a round hole, about

* From hence it ariſes that black bodies, when expoſed to the ſun, become ſooner heated than all others.

one-

one-third of an inch in diameter at C, through which a ray of light L I paſſing, falls on the priſm D E F, by that it is refracted out of the direction I F, in which it would have proceeded into another G H, and falling on the paper M N S C, will there form an oblong ſpectrum P Q, whoſe ends will be ſemicircular, and its ſides ſtrait; and if the diſtance of the priſm from the paper be about eighteen feet, it will be ten inches long, and two inches wide.

Now this ſpectrum will exhibit all the primary colours; for the rays between P and V, which are the moſt refracted, will paint a deep violet; thoſe between V and I, indigo; thoſe between I and B, blue; thoſe between B and G, green; thoſe between G and Y, yellow; thoſe between Y and O, orange; and thoſe between O and R, being the leaſt refracted, an intenſe red*. The colours between theſe

* For this reaſon it is that the rays which are near the edges of a lens have different degrees of

refraction,

ſpaces will not be every where equally intenſe, but will incline to the neighbouring colour; thus the part of the orange next to R, will incline to a red, and that next to Y, to a yellow; and ſo of the reſt.

RECREATION XXXIV.

From two or more of the primary colours, to compoſe others that ſhall, in appearance, reſemble thoſe of the former.

BY mixing the two homogeneal colours red and yellow, an orange will be produced, ſimilar in appearance to that in the ſeries of primary colours; but the light of the one being homogeneal, and that of the other heterogeneal, if the former be viewed through a priſm it will remain unaltered, but the other will be reſolved into its component colours, red and yellow. In like manner other contiguous

refraction, and tinge the object with different colours.

ho-

homogenial colours may compound new colours; as by mixing yellow and green, a colour between them is formed; and if blue be added, there will appear a green that is the middle colour of those three. For the yellow and blue, if they are equal in quantity, will draw the intermediate green equally toward them, and keep it, as it were, in equilibrio, that it verge not more to the one than to the other. To this compound green there may be added some red and violet, and yet the green will not immediately cease, but grow less vivid; till by adding more red and violet it will become more diluted, and at last, by the prevalence of the added colours, it will be overcome, and turned into whiteness or some other colour.

In like manner if the sun's white, composed of all kind of rays, be added to any homogeneal colour, that colour will not vanish, nor change its species, but be diluted; and by adding more white, it will become

become continually more diluted. Lastly, if red and violet be mixed, there will be generated, according to their various proportions, various purples, such as are not like, in appearance, to the colour of any homogeneal light: and of these purples, mixed with blue and yellow, other new colours may be composed.

RECREATION XXXV.

Out of three of the primary colours, red, yellow, and blue, to produce all the other prismatic colours, and all that are intermediate to them.

PROVIDE three panes of glass of about five inches square, (see Plate XIII. Fig. 2.) and divide each of them, by parallel lines, into five equal parts.

Take three sheets of very thin paper, which you must paint, lightly, one blue, another yellow, and the third red *. Then

* You must use water colours for this purpose: the blue may be that of Prussia, and very bright; the

paste on one of the glasses five pieces of the red paper, one of which must cover the whole glass, the second only the four lower divisions, the third the three lower, the fourth the two lowest, and the fifth the last division only. On the other two glasses five pieces of the blue and yellow papers must be pasted in like manner.

You must also have a box of about six inches long, and the same depth and width as the glasses: it must be black on the inside: let one end be quite open, and in the opposite end there must be a hole large enough to see the glasses completely. It must also open at the top, that the glasses may be placed in it conveniently.

When you have put any one of these glasses in the box, and the open end is

the red, carmine; and the yellow gambooge, mixed with a little saffron. These colours must be laid very light and even, on both sides of the paper.

turned toward the sun, you will see five distinct shades of the colour it contains.

If you place the blue and yellow glasses together, in a similar direction, you will see five shades of green distinctly formed. When the blue and red glasses are placed, a bright violet will be produced; and by the red and yellow, the several shades of orange.

If, instead of placing these glasses in a similar position, you place the side AB of the yellow glass, against the side BD of the blue, (Plate XIII. Fig. 3.) you will see all the various greens that produced by nature *; if the blue and red glasses be placed in that manner, you will have all the possible varieties of purples, violets, &c. and lastly, if the red and orange

* In the first position of the glasses the quantity of blue and yellow being equal, the same sort of green was constantly visible: but by thus inverting the glasses, the quantity of the colours being constantly unequal, a very pleasing variety of tints is produced.

glasses

glasses be so placed, there will be all the intermediate colours, as the marygold, aurora, &c.

RECREATION XXXVI.

By means of the three primary colours, red, yellow, and blue, together with light and shade, to produce all the gradations of the prismatic colours.

ON seven square panes of glass paste papers that are painted with the seven prismatic colours, in the same manner as in the last Recreation. The colours for the orange, green, indigo, and violet, may be made by mixing the other three. Then with bistre *, well diluted, shade a sheet of very thin paper, by laying it light on both its sides. With pieces of this paper cover four-fifths of a glass, of the same size with the others, by laying one piece on the four lowest divisions, another on

* The bistre here used must be made of soot, not that in stone.

the three loweſt, a third on the two loweſt, and the fourth on the loweſt diviſion only: and leaving the top diviſion quite uncovered.

When one of the coloured glaſſes is placed in the box, together with the glaſs of ſhades, ſo that the ſide A B of the one be applied to the ſide B C of the other, as in Fig. 3. of the laſt Recreation, the ſeveral gradations of colours will appear ſhaded in the ſame manner as a drapery judiciouſly painted with that colour.

It is on this principle that certain French artiſts have proceeded in their endeavours to imitate, by deſigns printed in colours, paintings in oil: which they do by four plates of the ſame ſize, on each of which is engraved the ſame deſign. One of theſe contains all the ſhades that are to be repreſented, and which are painted either black, or with a dark grey. One of the three other plates is coloured with blue, another

another with red, and the third with yellow: each of them being engraved in thoſe parts only which are to repreſent that colour *, and the engraving is either ſtronger or weaker, in proportion to the tone of colour that is to be repreſented †.

Theſe four plates are then paſſed alternately under the preſs, and the mixture of their colours produces a print that bears

* When a red drapery is required, it is engraved on the plate aſſigned to that colour; and ſo of yellow and blue: but if one of the other colours be wanting, ſuppoſe violet, it muſt be engraved on thoſe that print the red and blue: and ſo of the reſt. The plates of this kind have been hitherto engraved in the manner of mezzotinto, but theſe, unleſs they are ſkilfully managed, ſoon become ſmutty. Engravings in the manner of the crayon, would perhaps anſwer better.

† The principal difficulty in this ſort of engraving ariſes from want of a ſkilful management, in giving each plate that preciſe degree of engraving which will produce the tone of colour required. If a bright green is to be repreſented, there ſhould be an equal quantity of graving on the red and yellow plates: but if an olive green, the yellow plate ſhould be engraved much deeper than the red.

no ſmall reſemblance to a painting. It muſt be confeſſed, however, that what has been hitherto done of this kind, falls far ſhort of that degree of perfection, of which this art appears ſuſceptible. If they who engrave the beſt in the manner of the crayon, were to apply themſelves to this art, there is reaſon to expect they would produce far more finiſhed pieces than we have hitherto ſeen.

RECREATION XXXVII.

The magical priſm.

MAKE a hole in the window-ſhutter of a dark room, through which a broad beam of light may paſs, that is to be refracted by the large glaſs priſm ABC, (Plate XIII. Fig. 4.) which may be made of pieces of mirrors cemented together, and filled with water.

Provide another priſm DEF, made of three pieces of wood; through the middle of of this there must pass an axis on which it is to revolve. This prism must be covered with white paper, and each of its sides cut through in several places, so as to represent different figures, and those of each side should likewise be different. The inside of this prism is to be hollow, and made quite black, that it may not reflect any of the light that passes through the sides into it.

When this prism is placed near to that of glass, as in the figure, with one of its sides E F, perpendicular to the ray of light, the figures on that side will appear perfectly white: but when it comes into the position *g h*, the figures will appear yellow and red, and when it is in the position *k l*, they will appear blue and violet. As the prism is turned round its axis, the other sides will have a similar appearance. If instead of a prism a four or five-sided figure be here used, the appearances will be still further diversified.

This phenomenon arises from the different refrangibility of the rays of light. For when the side EF is in the position *g h*, it is more strongly illuminated by the least refrangible rays, and wherever they are predominant, the object will appear red or yellow. But when it is on the position *k l*, the more refrangible rays being then predominant, it will appear tinged with blue and violet.

RECREATION XXXVIII.

The solar magic lantern.

PROCURE a box, of about a foot high, and eighteen inches wide, or such other similar dimensions as you shall think fit; and about three inches deep. Two of the opposite sides of this box must be quite open, and in each of the other sides let there be a groove, wide enough to pass a stiff paper or pasteboard. This must box be fastened against a window on which the sun's rays fall direct. The rest of the window

dow ſhould be cloſed up, that no light may enter,

Provide ſeveral ſheets of ſtiff paper, which muſt be blacked on one ſide. On theſe papers cut out ſuch figures as you ſhall think proper, and placing them alternately in the grooves of the box, with their blacked ſides towards you, look at them through a large and clear glaſs priſm; and if the light be ſtrong, they will appear to be painted with the moſt lively colours in nature. If you cut on one of theſe papers the form of the rainbow, about three quarters of an inch wide, you will have a lively repreſentation of that in the atmoſphere.

This Recreation may be further diverſified, by paſting very thin papers, lightly painted with different colours, over ſome of the parts that are cut out: which will appear to change their colours, when viewed through the priſm, and to ſtand out from

from the paper, at different diſtances, according to the different degrees of refrangibility, of the colours with which they are painted.

For greater convenience, the priſm may be placed in a ſtand on a table, at the height of your eye, and made to turn round on an axis, that when you have got an agreeable proſpect, you may fix it in that poſition. This experiment may be made at a trifling expence; and, if properly conducted, will afford no ſmall entertainment.

RECREATION XXXIX.

The artificial rainbow.

OPPOSITE a window into which the ſun ſhines direct, ſuſpend a glaſs globe filled with water, by a ſtring that runs over a pulley, ſo that the ſun's rays may fall on it. Then drawing the globe gradually

gradually up, when it comes to the height of about forty degrees *, you will ſee, by placing yourſelf in a proper ſituation, a purple colour in the glaſs, and by drawing it gradually up higher, the other priſmatic colours, blue, green, yellow, and red, will ſucceſſively appear; after which the colours will diſappear, till the globe is raiſed to about fifty degrees, when they will again be ſeen, but in an inverted order, the red appearing firſt, and the blue or violet laſt: and when the globe comes up to little more than fifty-four degrees they will totally vaniſh.

Theſe appearances ſerve to explain the phenomena of natural rainbows, of which there are frequently two; the one being about eight degrees above the other, and the order of their colours is inverted, as

* That is, if you ſuppoſe an arch of a circle to be drawn from the horizon to the zenith, and divided into ninety equal parts or degrees, the globe muſt be raiſed to the height of forty of thoſe degrees.

in this experiment, red being the uppermost colour in the lower bow, and violet in the other.

The rainbow is not in the clouds, but in the falling rain, and always opposite the sun. The different order of the colours in the bows arises from their different reflections; those of the under bow being caused by two refractions and one reflection, and those of the upper, by two refractions and two reflections, and therefore the colours of this are less bright than the other, their strength being diminished by every reflection.

Now, it has been proved by repeated experiments, that forty degrees forms the greatest angle by which the most refrangible rays can, after one reflection, be refracted to the eye; and that something more than forty-two degrees forms the greatest angle, under which the least refrangible rays can come to the eye after one reflection. Therefore all the colours of the lower bow must lie in the space of less than two degrees. In like manner it has been proved, that fifty degrees make the least angle under which the least refrangible rays can be visible to the eye after two reflections; and that about fifty-four degrees will be the least angle under which the most refrangible rays can come to the eye after two reflections. Therefore all the colours of the upper bow must be in less than four degrees.

It follows from what is here said, that all rainbows are of a circular form and equal magnitude, and as they are always opposite the sun, the parts we see of them must be in proportion to his height above the horizon: when his altitude is forty degrees, only the upper rainbow can be visible, and when it is fifty-four degrees there can be no rainbow; but as the sun's height, during the winter half year, is never equal to forty degrees, there may then be always two bows visible.

RECRE-

RECREATION XL.

The prismatic camera obscura.

MAKE two holes F, *f*, (Plate XIII. Fig. 5.) in the shutter of a dark chamber, near to each other, and against each hole place a prism ABC, and *abc*, in a perpendicular direction, that their spectrums NM may be cast on the paper in a horizontal line, and coincide with each other; the red and violet of the one being in the same part with those of the other. The paper should be placed at such a distance from the prisms that the spectrum may be sufficiently dilated.

Provide several papers nearly of the same dimension with the spectrum, cross these papers, and draw lines parallel to the divisions of the colours. In these divisions cut out such figures as you shall find will have an agreeable effect, as flowers, trees, animals, &c.

When

When you have placed one of these papers in its proper position, hang a black cloth or paper behind it, that none of the rays that pass through may be reflected, and confuse the phenomenon. The figures cut on the paper will then appear strongly illuminated with all the original colours of nature.

If while one of the prisms remains at rest, the other be revolved on its axis, the continually alteration of the colours will afford a pleasing variety; which may be further increased by turning the prism round in different directions.

When the prisms are so placed that the two spectrums become coincident in an inverted order of their colours, the red end of one falling on the violet end of the other, if they be then viewed through a third prism D H, held parallel to their length, they will no longer appear coincident, but in the form of two distinct

spectrums,

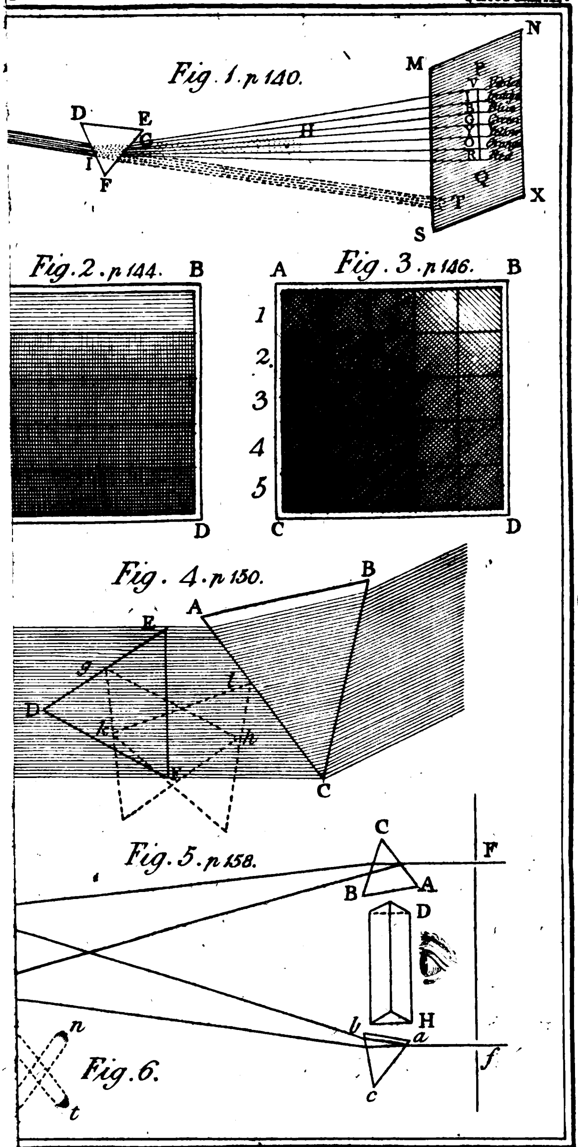
ſpectrums, *p t*, and *n m*, (Fig. 6.) croſſing one another in the middle, like the letter X. The red of one ſpectrum and the violet of the other, which were coincident at N M, being parted from each other by a greater refraction of the violet to *p* and *m*, than that of the red to *n* and *t*.

This Recreation may be further diverſified by adding two other priſms, that ſhall form a ſpectrum in the ſame line, and contiguous to the other; by which not only the variety of figures, but the viciſſitude of colours will be conſiderably augmented.

RECREATION XLI.

The diatonic ſcale of colours.

THE illuſtrious Newton, in the courſe of his ſagacious inveſtigations of the properties of light, diſcovered that the length of the ſpaces which the ſeven primary colours poſſeſs in the ſpectrum, exactly correſponds to thoſe of chords that



J. Lodge sculp.

ſpectrums, $p\,t$, and $n\,m$, (Fig. 6.) croſſing one another in the middle, like the letter X. The red of one ſpectrum and the violet of the other, which were coincident at N M, being parted from each other by a greater refraction of the violet to p and m, than that of the red to n and t.

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Fig. 1. p. 140.

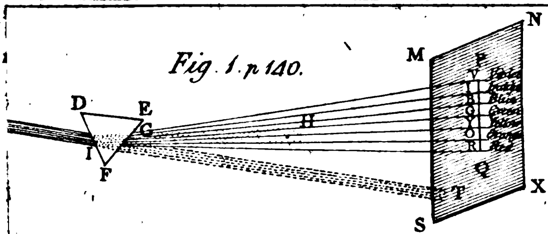


Fig. 2. p. 144.

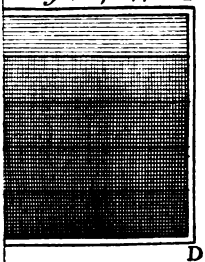


Fig. 3. p. 146.

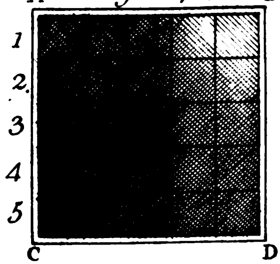


Fig. 4. p. 150.

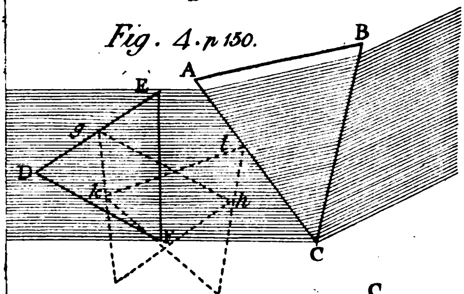


Fig. 5. p. 158.

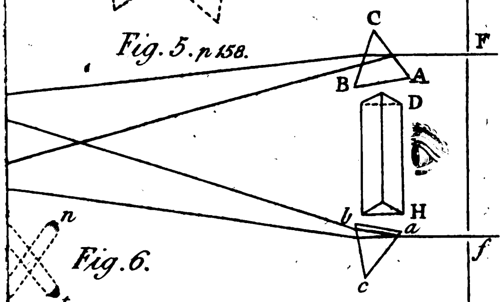


Fig. 6.

J. Lodge Sculp.

that ſound the ſeven notes in the diatonic ſcale of muſic. As is evident by the following experiment.

On a paper in a dark chamber let a ray of light be largely refracted into the ſpectrum A F T M G P, (Plate XIV. Fig. 1.) and mark the preciſe boundaries of the ſeveral colours, as *a*, *b*, *c*, &c. Draw lines from thoſe points perpendicular to the oppoſite ſide, and you will find that the ſpaces M *r f* F, by which the red is bounded; *q p e d*, by which the orange is bounded; *p o c d*, by which the yellow is bounded, &c. will be in exact proportion to the diviſions of a muſical chord for the notes of an octave, that is, as the intervals of theſe numbers 1, $\frac{8}{9}$, $\frac{5}{6}$, $\frac{3}{4}$, $\frac{2}{3}$, $\frac{3}{5}$, $\frac{9}{16}$, $\frac{1}{2}$.

RECREATION XLII.

Colorific music.

FATHER Caſtel, a Frenchman, in a curious book he has publiſhed on Chromatics, ſuppoſes the note *ut* to anſwer to blue in the priſmatic colours, the note *re* to yellow, and *mi* to red. The other tones he refers to the intermediate colours, from whence he conſtructs the following gamut of colorific muſic.

Ut	Blue
Ut ſharp	Sea-green
Re	Bright green
Re ſharp	Olive green
Mi	Yellow
Fa	Aurora
Fa ſharp	Orange
Sol	Red
Sol ſharp	Crimſon
La	Violet
La ſharp	Blue violet
Si	Sky blue
Ut	Blue

This gamut, according to his plan, is to be continued in the ſame manner for the fol-

following octave; except that the colours are to be more vivid.

He ſuppoſes that theſe colours, by ſtriking the eye in the ſame ſucceſſion as the ſounds, to which he makes them analogous, do the ear, and in the ſame order of time, they will produce a correſpondent ſenſation of pleaſure in the mind. It is on theſe general principles, which F. Caſtel has ingeniouſly dilucidated in his treatiſe, that he has endeavoured, though with little ſucceſs, to eſtabliſh his ocular harpſichord.

The conſtruction of this inſtrument, as here explained, will ſhow that the effects produced by colours by no means anſwer thoſe of ſounds, and that the principle relation there is between them, conſiſts in the duration of the time that they reſpectively affect the ſenſes.

Between two circles of paſteboard, of ten inches diameter, AB and CD (Plate

XIV. Fig. 2.) encloſe a hollow paſteboard cylinder E, eighteen inches long. Divide this cylinder into ſpaces half an inch wide, by a ſpiral line that runs round it from top to bottom, and divide its ſurface into ſix equal parts by parallel lines drawn between its two extremities; as is expreſſed in the figure.

Let the circle A B, at top, be open, and let that at bottom, CD, be cloſed, and ſupported by an axis or ſcrew, of half an inch diameter, which muſt turn freely in a nut placed at the bottom of a box we ſhall preſently deſcribe. To the axis juſt mentioned adjuſt a wooden wheel G, of two inches and a half in diameter, and that has twelve or fifteen teeth, which take the endleſs ſcrew H. Let this cylinder be incloſed in a box I L M N (Fig. 3.) whoſe baſe is ſquare, and at whoſe bottom there is a nut, in which the axis F turns. Obſerve, that the endleſs ſcrew H, ſhould come out of the box, that it may receive the

the handle O, by which the cylinder is to be turned.

This box being closed all round, place over it a tin covering A, which must be perforated in different parts; from this cover there must hang three or four lights, so placed that they may strongly illumine the inside of the cylinder. In one side of this box (which should be covered with pasteboard) cut eight apertures, *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, of half an inch wide, and one-third of an inch high; they must be directly over each other, and the distance between them must be exactly two inches. It is by these openings, which here correspond to the musical notes, that the various colours analogous to them, are to appear; and which being placed on the pasteboard cylinder, as we have shown, are reflected by means of the lights placed within it.

It is easy to conceive, that when the handle O is turned, the cylinder in conſequence riſing half an inch, if it be turned five times round, it will ſucceſſively ſhow, at the openings made in the ſide of the box, all thoſe that are in the cylinder itſelf, and which are ranged according to the direction of the inclined lines drawn on it. It is therefore according to the duration of the notes which are to be expreſſed, that the apertures on the cylinder are to be cut. Obſerve, that the ſpace between two of the parallel lines drawn vertically on the cylinder, is equal to one meaſure of time, therefore for every turn of the cylinder, there are ſix meaſures, and thirty meaſures for the air that is to be played by this inſtrument.

The ſeveral apertures being made in the ſide of the cylinder, in conformity to the notes of the tune that is to be expreſſed, they are to be covered with double pieces of very thin paper, painted on both ſides with the colours that are to repreſent the muſical notes.

This

Fig. 1. p. 161.

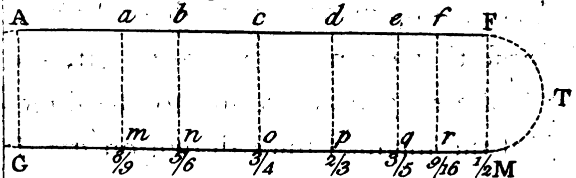


Fig. 2. p. 163.

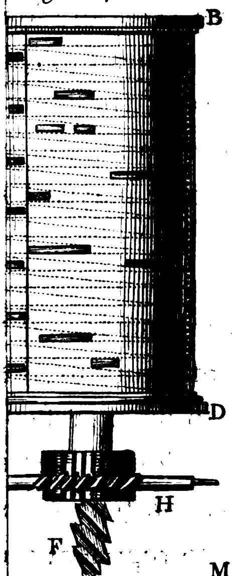
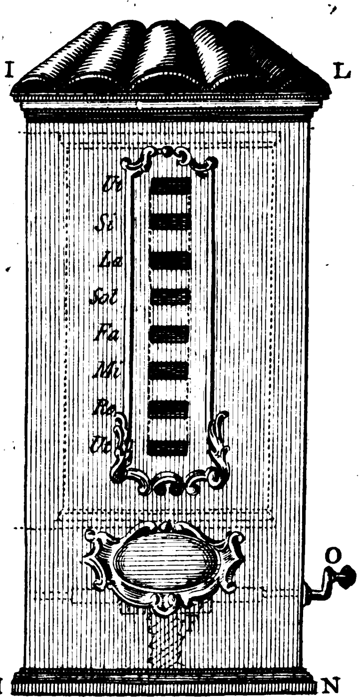


Fig. 3. p. 164.



J. Lodge Sculp.

This Recreation might be executed in a different manner, and with a much greater extent; but as the entertainment would not equal the trouble and expence, we have thought it sufficient to give the above piece, by which the reader will be enabled to judge how far the analogy supposed by F. Castel really exists.

This article is taken from M. Guyot, who, though he commends the good father's ingenuity and industry, attributes but little merit to his scheme. Not having seen F. Castel's book, we cannot pretend to judge of the merit of his plan. It is evident, however, from the foregoing Recreation, that there is a much stronger relation between sounds and colours than M. Guyot seems to imagine.

PERSPECTIVE RECREATIONS.

If the following recreations do not directly belong to optics, they have so great a resemblance to it, that perhaps they could not be introduced any where else with so much propriety.

ANAMORPHOSES.

RECREATION XLIII.

To draw on a plane surface an irregular figure, which, when seen from a proper point of view, will appear exactly similar to a given figure.

ON a paper or pasteboard draw the parallelogram ABCD (Pl. XV. Fig. 1.) of what size you please, provided the sides AB and CD be longer than AC and BD; let it be, for example, four inches long and three wide. Divide it into twelve equal parts, and each of those into four other

other equal parts *. On this parallelogram draw the regular figure that you would have represented, in a distorted form, on the plane.

Draw on a paper the line B A (Fig. 2.) indefinite toward A. Directly over the point B, mark the point of view C, and let fall the perpendicular C B. On the line A B mark the point D, and draw from the point of view C, to that point D, the line C D. On the same line, and at a convenient distance from the point C, draw the line F G, of the same length with A C (Fig. 1.) let it be perpendicular to the line C D, and by which it must be bisected. From the point C to F and G, draw the two lines C F and C G, and continue them till they meet the line A B at the points H and O.

* The smaller the divisions are, the more easy it will be to represent the subject with precision.

The

The line H O will then appear to the eye at C of the ſame dimenſion with the line FG, which is equal to the width of the parallelogram A B C D, as muſt neceſſarily follow from the principle laid down in the part of Optics; that is, becauſe both theſe lines appear under the ſame angle H C O.

Then divide the line F G into the ſame number of parts with the ſide of the parallelogram A C, (Fig. 1.) and from the point of view C, to the line A B, draw the lines C I, C L, C M, C N, through the diviſions in the line F G.

On another paper draw the line A B (Fig. 3.) equal to the line C A, (Fig. 2.) and at its extremity B, erect the indefinite perpendicular B C. From the point B of the line A B to the point E, in the ſame line, ſet off a ſpace equal to the line C F. (Fig. 2.) At the point E divide the line A B by the perpendicular H I, equal to

C D,

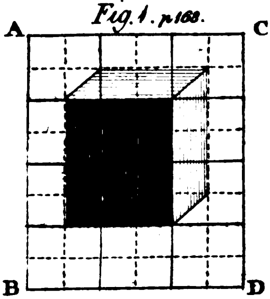
C D, (Fig. 1.) that is, equal to the length of the parallelogram. This line muſt alſo be divided into two equal parts by the line A B.

From the point B to the points H and I, draw the lines B H and B I, and continue them towards C and D. Take the diſtances that are between H and I, L D, M and N, (Fig. 2.) and tranſpoſe them to the line AB (Fig. 3.) from A to I, L, M, N, O, and draw the lines Y, Z, perpendicular to each of theſe diviſions. Divide the line C D into eight equal parts, and draw the lines B G, B Q, B R, B S, B T, and B V.

Theſe diviſions being made, the trapezium CHDI will be divided into as many parts as the parallelogram ABCD, (Fig. 1.) and all theſe diviſions, though of themſelves irregular, will appear to the eye, when placed at the point C, (Fig. 2.) of the ſame figure and magnitude as the parallelogram: all the lines that form the divisions included in the trapezium CHDI, being seen under similar angles. In order to facilitate the transposing the several parts of the design contained in the parallelogram, to the trapezium, it will be proper to number the principal divisions. The whole, moreover, should be traced with great precision *. Observe, that all the right lines in the parallelogram form as many right lines in the trapezium, therefore when you have marked their extremities, you may draw them with a ruler from one point to the other. With regard to curve lines, you will judge of their direction by the points where they cut the divisions of the parallelograms, and transpose

* This method of drawing an irregular figure is taken from M. Guyot, and differs from those that are given by Niceron and Ozanam, as it appears more exact to place the design that is to be represented in such manner that the ray, or principal point of view, may fall perpendicular on the center of the supposed picture placed at F G.

Fig. 1. p. 168.



Fi

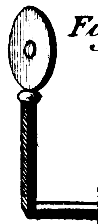


Fig. 2. p. 169.

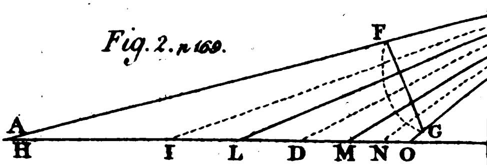
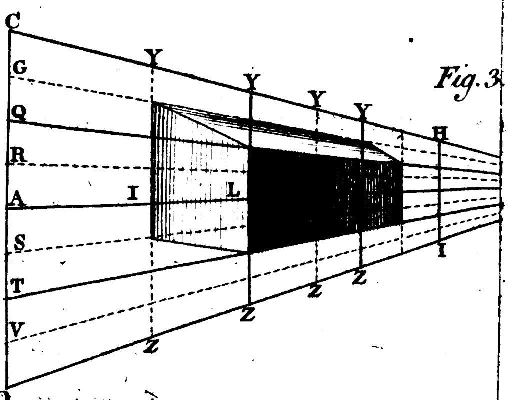


Fig. 3



pose them to the corresponding divisions of the trapezium.

Note, care must be taken that the paper on which the distorted figure is drawn be well stretched on a plane, that its surface may be quite even. You should also examine it attentively from the point of view; and for that purpose it will be convenient to have a little circle of brass, through which a hole of about two tenths of an inch is made, and placed upon a stand (see Fig. 4.) By that overture this piece of perspective illusion will produce an agreeable surprize.

Observe, that the distance of the point of view from the picture may be taken at pleasure, provided it be not less than its width. When the point of view is near the picture it appears more deformed than when it is at a greater distance, for the parts then become more extended toward CD: from whence it follows, that if we would

would execute a design of this sort on the side of a gallery, it must be regulated according to the dimensions of the part on which it is to be drawn. These subjects, when well executed, at full length, are highly agreeable, and appear the more extraordinary, as the eye not being able to view them but by parts, (when walking in the gallery *) we cannot form the least idea of what they will present when seen from a proper point of view, where the effect is truly admirable.

* There are, at the convent of Minims in the Place Royale at Paris, several subjects of this kind, painted on the walls of the cloister by P. Niceron, who has published an excellent treatise on this art. Among others, the figure of a Magdalen daily excites the curiosity of a number of connoisseurs. Unfortunately, these pieces, which have suffered by time, have not been properly repaired.

RECRE-

RECREATION XLIV.

To draw an irregular figure on a plane, which being seen from two opposite points of view, shall represent two different regular objects.

MAKE choice of a plane of a convenient size, suppose two feet long and half a foot wide. Draw the line A B of the same length, (Plate XVI. Fig. 1.) continue it on each side to C and D, and erect the perpendiculars CF and DG to the height of about three inches. Draw the lines A F and B G, and divide the line A B into six equal parts at the points S, (or into any other number you shall think fit). From the two points of view F and G draw the lines F S and G S, to those six divisions.

Then on the line G A set off the distance GB, and on the line FB the distance FA, and draw the two lines BH and A I, which will determine the width of the two subjects

jects you are to represent on the plane, and are to be viewed, the one from the point F, and the other from G; and of which the unequal divisions formed by the lines GS and FS, will determine those that are to correspond to the separate and inclined parts of the irregular figure which is to be seen from the points of view F and G.

This first preparation being made, draw the parallelogram ABCD (Fig. 2.) of the same length with the line AB in the preceding figure, and about six inches wide: divide it into two equal parts by the line FG, which continue to H and I, equal to the distance there is between CA and DB (Fig. 1.)

From the points AOSB (Fig. 1.) let fall the perpendiculars AA, OL, SL, and BC, on the line AC (Fig. 2.) and from the points L draw the lines LM parallel to AB.

From

From the four angles of the parallelogram A B C D, draw the lines A I and B I to the point of view I, and thoſe of C H and D H to the other point of view H; theſe lines will determine by the ſections at X and Y the apparent height of the figure.

Then divide the lines A B and C D, into as many equal parts as you ſhall think proper, and from thoſe points draw the lines N I and N H.

Next, draw on a paper the two parallelograms F G H I, L M N O, (Fig. 3.) and on them you are to draw the two different deſigns that you would repreſent in the diſtorted figure. Let each of theſe parallelograms be of an equal height with the diſtance X Y, (Fig. 2.) and of the ſame length as H B (Fig. 1.) Divide their height F H or L N, according to the diviſions of the line X Y (Fig. 2.) and their length H I or N O, according to thoſe of the line B H (Fig. 1.)

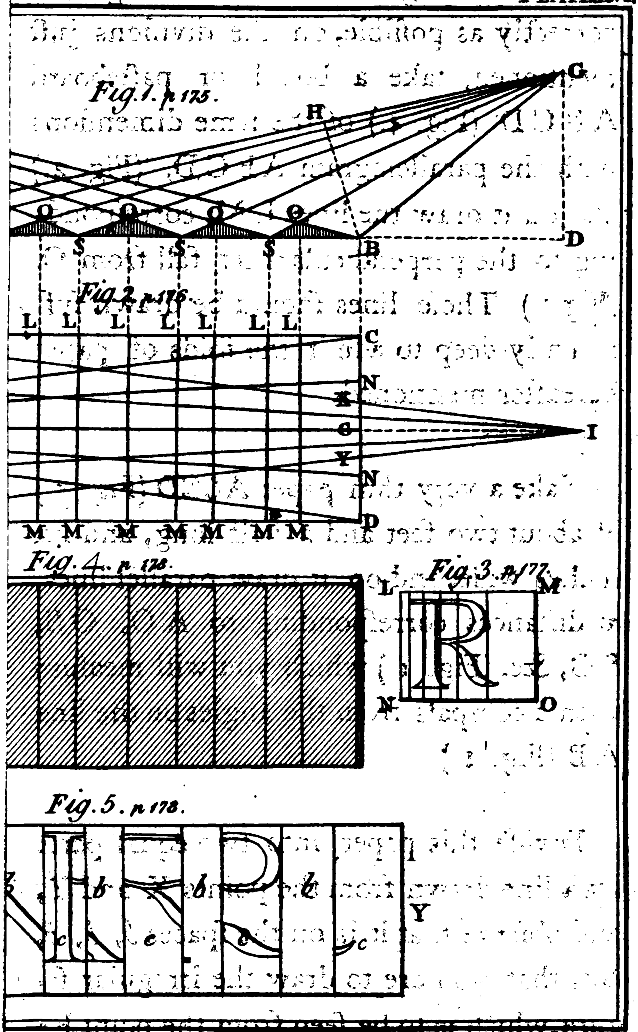
After having drawn the two designs, as correctly as possible, on the divisions just mentioned, take a board or pasteboard ABCD (Fig. 4.) of the same dimensions with the parallelogram ABCD, (Fig. 2.) and on it draw the lines LM, corresponding to the perpendiculars let fall from O. (Fig. 1) These lines should be drawn sufficiently deep to admit the folds of paper hereafter mentioned.

Take a very thin paper ABCD (Fig. 5.) of about two feet and a half long, and six inches wide, and on it draw parallel lines, at distances corresponding to AO, OS, SO, &c. (Fig. 1.) which you will measure with a compass from the angles on the line AB (Fig. 1.)

Divide this paper into two equal parts by a line drawn from the points X and Y, and observe that it is on the spaces *b*, *b*, *b*, &c. that you are to draw the irregular figure which is to be seen from the point F; and

6

PLATE XVI.



J. Lodge sculp.

and on thoſe of *c*, *c*, *c*; &c. that which is to be ſeen from the point G.

On each of theſe ſpaces draw the lines, not punctuated, of the parallelogram A B C D (Fig. 2.) that terminate in the points H and I. Then trace on the ſame paper all the ſtrokes of the two figures drawn on the two parallelograms, (Fig. 3.) carefully obſerving the ſeveral diviſions to which they correſpond.

When this irregular figure is quite finiſhed, fold the paper according to the diviſions that have been drawn on it, ſo that each of the diviſions S, may turn one way, and each of the diviſions O, the other way; and paſte the whole on a board, in ſuch a manner that the folds made on the blank ſide of the paper, may anſwer to the lines traced in the board. On the paper thus paſted lay ſomething that may keep it in proper form till the paſte is dry. Then let it be ſo placed that ſix of its diviſions may be oppoſite to each of the points of view F and G.

To diſtinguiſh the objects on the parallelogram with greater preciſion, you muſt have (as in the foregoing Recreation) two little circles, with a ſmall hole in each, and place them exactly on the points of view that have been fixed. The eye being then placed at either of thoſe points, will diſcern the regular figure; but when the ſcheme is viewed in front, it preſents a form ſo diſtorted, that it is impoſſible to conjecture what it is intended to repreſent.

Obſerve, This deſign differs in the conſtruction from that in the firſt Recreation; as here, the diviſions drawn on the irregular figure regulate thoſe of the two other figures. It is indeed more difficult, but then it is alſo more entertaining; and with a little application it may be eaſily executed, as nothing more is neceſſary than to to transfer the divisions carefully from one figure to the other.

To perform this sort of anamorphosis with more celerity, you may draw the plan on a pasteboard, and placing a transparent paper over it, trace the subject thereon; the same pasteboard will serve to execute, equally well, all sorts of subjects.

RECREATION XLV.

To draw, on the base of a cone, an irregular figure, which shall appear, when seen from a proper point of view, not only regular, but elevated above the surface of the cone.

THE geometric method that might be here given for drawing the figure proposed, being extremely tedious and difficult, on account of the various curves that it is necessary to draw on the base of the cone, we shall here describe a more simple method, by making use of a lamp.

This method may likewise be used in the drawing distorted subjects on all irregular surfaces, whatever their figure may be.

Let E F G (Plate XVII. Fig. 1.) be the cone, on the basis of which a distorted figure is to be drawn, that being viewed from the point H, shall appear regular, and exactly resembling that which is placed at N M. Place the cone in a circular overture made in the board A B C D, which should be supported by four feet, that the point of the cone may not touch the table on which it stands. Fix at the end of the board an upright piece I, that is to hold a small circle of brass, through which is made a hole H, of two tenths of an inch in diameter, that serves for the point of view.

Prepare a lamp as A, (Fig. 2.) the light of which may be raised or lowered at pleasure, and to which is fixed a brass arm B C, bearing a sort of funnel D, in the shape

shape of a truncated cone, and whose opening at the end next the light is not more than three or four tenths of an inch in diameter.

Draw the subject you would represent on the base of the cone, on a piece of glass of equal height with the space M N*, that is, of the apparent height of the diameter E F, of the base of the cone when seen from the point H: place it perpendicular on the board at the point F, that is, at the extremity of the cone.

These preparations being made, take away the piece that bears the point of view H, and place the lamp, so prepared, in such manner that the light may be exactly where the point H was. Its rays then passing through the glass at M N, will en-

* It must be drawn with a very light stroke, and you must make use of a colour that is quite opaque.

 lighten

lighten all the lower surface of the cone, and there show, in a distorted form, the subject that is painted on the glass.

Then draw with a pencil all the strokes of the shadow that are on the cone; and taking away the light, place the point of view H, and see if what you have drawn correspond with the subject on the glass, correcting what imperfections there may chance to be. In the last place, colour the subject so traced on the cone, with the utmost attention, inspecting your work from time to time from the point of view, before you give it the finishing strokes.

When the figure that is drawn and painted on the base of the cone is viewed from the point H, it appears to be at the same point where the glass MN was placed, and in the same form that it was painted on that glass. The eye even perceives it above the surface of the board in which the cone is placed, and thereby receives a remarkable and pleaſing illuſion.

Note, This manner of drawing diſtorted figures by means of a lamp and tranſparent glaſs, may be advantageouſly uſed for all irregular figures that are difficult to draw geometrically. The ſubjects that are drawn on the glaſs may alſo be ſhaded and coloured, in the ſame manner as for the camera obſcura; in order to have the appearance of colours on the diſtorted picture.

If a circle be deſcribed on paper or paſteboard, and placed firm upon the table, where the cone is ſuppoſed to be, it will have preciſely the ſame effect.

RECREATION XLVI.

To draw, easily and correctly, a landscape or any other object, without being obliged to observe the rules of perspective, and without the aid of the camera obscura.

PROCURE a box of pasteboard A B C D (Plate XVII. Fig. 3.) of about a foot and a half long, and made in the shape of a truncated pyramid, whose base B D F G is eight inches wide, and six inches high. Fix to the other end of it a tube of four or five inches long, and which you can draw out from the box more or less. Line the inside of the box with black paper, and place it upon a leg or stand of wood H, and on which it may be elevated or depressed by the hinge I.

Take a small frame of wood A B C D (Fig. 4.) and divide it at every inch by lines of black silk drawn cross it, forming forty-eight ty-eight equal parts; divide these into still smaller equal parts, by lines of finer silk*; fix this frame at the end BD, as the base of the pyramid.

Provide a drawing paper, divided into the same number of parts as is the frame, by lines lightly drawn in chalk. It is not material of what size these divisions are; that will depend entirely on the size you propose to draw the objects by this instrument.

Place this instrument opposite a landscape, or any other object that you want to draw, and fix the leg firmly on, or in the ground, that it may not shake: then turning it to the side you choose, raise or incline it, and put the tube further in or out, till you have gained an advantageous view of the object you intend to draw.

* The different size of the silk serves to distinguish more readily the corresponding divisions.

Place

the opening to which E F G H, ſhould be a little leſs than the print. Cover this opening with a glaſs, and paint all the ſpace between it and the prints, which ſhould be about two or three inches, black. The frame that contains the ſky ſhould be about an inch behind the other. In the back part of this box, which is behind the prints, and which may be about four inches deep, place four or five ſmall candleſticks to hold wax lights, and cover that part entirely with tin, that it may be the more luminous.

When the print is placed between the wax lights and the opening in the front of the box, and there is no other light in the room, the effect will be highly pleaſing: eſpecially if the lights are at a ſufficient diſtance from each other, and not too ſtrong, that they may not occaſion any blots in the print. Thoſe prints that repreſent the riſing or ſetting of the ſun will have a very picturesque appearance.

Such

Such as represent conflagrations have also a striking effect.

Note. There should be two grooves for the print next the glass, that you may insert a second subject before you draw away the first: and that the lights in the back of the box may not be discovered.

You must not, thinking to make the print more transparent, cover it with varnish; for that will prevent the degradation of the colours from being visible. The frame should enter the side of the box by a groove, that a variety of subjects may be introduced.

RECREATION XLVIII.

Transparent illuminations.

THE box that is to enclose these subjects may be made in the same manner with that of the preceding Recreation, only observing that it will be proper to augment

ment the number of lights, and employ ſuch prints as are agreeable to the ſubject.

With a very ſmall circular tool you are to cut out all the places where the light is intended to appear, or where it is expreſſed, if the print repreſent an illumination. Particular care muſt be had to make uſe of the fineſt tools in thoſe parts of the print that are intended to appear at the greateſt diſtance.

Theſe prints muſt by no means be tranſparent, like thoſe in the preceding Recreation; on the contrary, they ſhould be printed on a thick paper, or rather it ſhould be doubled, that very little of the engraving may appear. Behind the print muſt be placed a very fine tranſparent paper, varniſhed, fixed on a frame, and lightly painted with a deep yellow, or ſaffron colour, which muſt be laid on thickeſt at thoſe places that are oppoſite the parts of the print that are to appear at the greateſt diſtance.

The

The ſetting of the ſun, ſucceeded by a night ſcene, may be very pleaſingly repreſented in this method. Thus: procure a landſcape, in which is the figure of the ſetting ſun, illuminated as above deſcribed. Let the bottom of this ſcene reſt upon an upright board in the box, of about two three inches high, and let it be gradually moved off that board, and lowered down to the bottom of the box, on the ſide next the glaſs, by which means the ſun will appear to deſcend. Let the lights then be gradually withdrawn: and change the firſt landſcape for a night ſcene, with the moon and ſtars, properly perforated. The yellow paper muſt be changed for one that is white and tranſparent, and the lights be again introduced; when the moon, ſtars, and other illuminated parts will appear in their natural form. For the more eaſy removing of the lights they may be all placed upon one ſtand, but at different diſtances.

This piece of illumination might alſo be put into the common optical machine; but the magnifying glaſs there uſed conſiderably enlarging the objects, the light reflected by the cut and tranſparent parts, then becomes greatly weakened, as it takes up a much larger ſpace; and that greatly diminiſhes the vivacity which is neceſſary to imitate nature, and to produce the illuſion. If, however, you are deſirous of viewing this piece by the magnifier, you muſt take away the inclined mirror which is placed in thoſe ſort of optical machines, and place the tranſparent picture or print in the front of the glaſs; otherwiſe it will be ſcarce poſſible to render it luminous, except by reflection, which affords but a very feeble light.

ACOUS-

ACOUSTICS.

THE ſcience of acouſtics inſtructs us in the nature of ſound. It is divided by ſome writers into diacouſtics, which explains the properties of thoſe ſounds that come directly from the ſonorous body to the ear; and catacouſtics, which treats of reflected ſounds: but ſuch diſtinction does not appear to be of any real utility.

DEFINITIONS.

1. Sounds are either acute or grave, ſimple or compound.

2. Thoſe ſounds that are ſhrill or ſharp are called acute: and

3. Thoſe that are deep or hollow, are called grave ſounds.

4. A ſimple ſound is that produced by a ſingle ſtroke on a ſonorous body; and compound ſounds are thoſe that proceed from ſeveral bodies ſtruck at the ſame time, or from ſeveral ſtrokes on different parts of the ſame body.

5. A chord is a ſtring of catgut, braſs, wire, &c. ſo ſtretched as when ſtruck to yield a diſtinct ſound.

6. A vibration is the regular, alternate motion of bodies, by which, when put out of their natural ſtate, they endeavour to return to it. Thus the ſtring A B (Pl. XVIII. Fig. 1. being forced out of its natural poſition to that of A *c* B, vibrates to *d*, and then to *e*, *f*, *g*, &c. till it returns to its firſt ſtate at A B.

APHORISMS.

1. All ſound is produced by an undulatory or wavelike motion of the air*, excited by the vibrations of a ſonorous body, proceeding from a ſtroke of ſome other body.

2. Acute ſounds ariſe from quick vibra-

* That air is the medium of ſound is evident from a bell placed in the receiver of an air-pump, which may be heard to a conſiderable diſtance before the air is exhauſted, but after, can ſcarce be diſtinguiſhed when quite near.

tions

tions of the parts of a body, and grave ſounds from ſlow vibrations.

3. Smooth and clear ſounds proceed from bodies that are homogeneous, and of an uniform figure; and harſh or obtuſe ſounds, from ſuch as are of a mixed matter and irregular figure.

4. In bodies of a ſimilar figure and dimenſion, and of equal elaſticity, their tones are in proportion to their denſities: the denſer the body the graver is the tone; therefore a bar of gold muſt have a graver ſound than one of ſilver, of equal dimenſions; ſuppoſing them to be of equal elaſticity.

5. If two bodies are compoſed of the ſame matter, and are of ſimilar figure, their tones will be in proportion to the quantities of matter. Thus, the tones of two globe of braſs will be to each other in proportion to their diameters.

6. The vibrations of chords is in proportion to their lengths, diameters, and tenſion.

7. All the vibrations of the ſame chord, as A*c*B, (Plate XVIII. Fig. 1.) A*d*B, A*e*B, &c. are made in the ſame time.

8. If two chords are of the ſame diameter or thickneſs, and equally ſtretched, their vibrations, in the ſame time, will be in proportion to their lengths inverſely, that is, a chord of ſix inches will make two vibrations while a chord of twelve inches makes one *.

9. If two chords frequently vibrate together they produce a concord; and the more frequent the coincidence of vibration, the more pleaſing the concord.

10. Sound is propagated in concentric

* From hence we learn how to divide any chord ſo that it may ſound the ſeven concords; as thus, divide the line A B (Plate XVIII. Fig. 2.) into two equal parts in C, and C B into two equal parts at D, and C D into two equal parts at E. Then A C will be to A B as $\frac{1}{2}$, that is, an octave, A C to A D as $\frac{2}{3}$, a fifth: A D to A B as $\frac{3}{4}$, a fourth. A C to A E as $\frac{4}{5}$, a third greater. A E to A D as $\frac{5}{6}$, a third leſſer. E B to A E as $\frac{3}{5}$, a ſixth greater, and A E to A B as $\frac{5}{8}$, a ſixth leſſer.

circles

circles every way round the sonorous body *.

11. All sounds, whether great or small, are of equal velocity.

12. The space passed over by sound is constantly equal in equal times, whether it come from a greater or less distance.

13. The motion of sound is at the rate of 1142 feet in a second, and no obstacles obstruct its progress; a contrary wind only a small matter diminishing its velocity †.

* The distance to which sounds may be heard is very great. Authors of credit relate that the sound of cannon has been heard 180 and 200 miles.

† By this axiom we are enabled to find the distance between objects that would be otherwise immeasurable. For example, suppose you see the flash of a gun in the night at sea, and tell seven seconds before you hear the report, it follows therefore, that the distance is seven times 1142 feet, that is twenty-four yards more than a mile and a half. In like manner if you observe the number of seconds between the lightning and the report of the thunder, you know the distance of the cloud from whence it proceeds.

14. The velocity of ſound is to that of a briſk wind as fifty to one.

15. The ſtrength of ſounds is greateſt in cold and denſe air, and leaſt in that which is warm and rarefied.

16. In all ſounds the angle of incidence is equal to that of reflection, that is, if a line be drawn perpendicular to the reflecting ſurface, the point from which the ſound iſſues, and that to which it is reflected, will be equally diſtant from the perpendicular line.

RECRE-

RECREATION XLIX.

The Æolipiles.

AN æolipile is a ſmall globe of braſs or other metal, into which a ſlender neck or pipe is inſerted. This ball, when made red hot, is caſt into a veſſel of water, which will ruſh into its cavity, then almoſt void of air. The ball being then ſet on the fire, the water, by the rarefaction of the internal air, will be forced out in ſteam, by fits, with great violence, and with a ſtrange noiſe.

If to the necks of two or more of theſe æolipiles there be fitted thoſe calls that are uſed by fowlers and hunters, and the æolipiles be then placed privately on the fire; as the ſteam ruſhes forth they will make ſuch a horrible noiſe, that a perſon who is ignorant of the contrivance cannot fail being greatly aſtoniſhed.

Great

partment. There may be likewiſe wires that go from the under jaw, and the eyes of the buſt, by which they may be eaſily moved.

A perſon being placed in the under room, and at a ſignal given applying his ear to one of the tubes, will hear any queſtion that is aſked; and immediately reply, moving at the ſame time the mouth and the eyes of the buſt, by means of the wires.

RECREATION LII.

A ſolar ſonata.

IN a large caſe, ſuch as is uſed for dials and ſpring clocks, the front of which, or at leaſt the lower part of it, muſt be of glaſs, covered on the inſide with gauze, let there be placed a barrel organ, which, when wound up, is prevented from playing, by a catch that takes a toothed wheel at the end of the barrel. To one end of this

this catch there must be joined a wire, at the end of which there is a flat circle of cork, of the same dimension with the inside of a glass tube, in which it is to rise and fall. This tube must communicate with a reservoir that goes across the front part of the bottom of the case, which is to be filled with spirits, such as is used in thermometers, but not coloured, that it may be the better concealed by the gauze.

This case being placed in the sun, the spirits will be rarified by the heat, and rising in the tube, will lift up the catch or trigger, and set the organ in play; which it will continue to do as long as it is kept in the sun; for the spirits cannot run out of the tube, that part of the catch to which the circle is fixed being prevented from rising beyond a certain point, by a check placed over it. Care must be taken to remove the machine out of the sun before the organ runs down, that its stopping may be evidently effected by the cold.

7 When

When the machine is placed against the side of a room on which the sun shines strong, it may constantly remain in the same place, if you enclose it in a second case, made of thick wood, and placed at a little distance from the other. When you want it to perform, it will be only necessary to throw open the door of the outer case, and expose it to the sun.

But if the machine be moveable, it will perform in all seasons by being placed before the fire; and in the winter it will more readily stop when removed into the cold.

A machine of this sort is said to have been invented by Cornelius Dreble, in the last century. What the construction of that was we know not; it might very likely be more complex, but could scarce answer the intention more readily.

RECRE-

RECREATION LIII.

An automatous harpſichord.

UNDER the keys of a common harpſichord let there be fixed a barrel, ſomething like that in a chamber organ, with ſtops or pins correſponding to the tunes you would have it play. Theſe ſtops muſt be moveable, ſo that the tunes may be varied at pleaſure. From each of the keys let there go a wire perpendicular down; the ends of theſe wires muſt be turned up for about one-fourth of an inch. Behind theſe wires let there be an iron bar, to prevent them from going too far back. Now, as the barrel turns round, its pins take the ends of the wires, which pull down the keys, and play the harpſichord. The barrel and wires are to be all encloſed in a caſe.

In the chimney of the ſame room where the harpſichord ſtands, or at leaſt in one adja-

adjacent, there muſt be a ſmoke jack, from whence comes down a wire, or cord, that paſſing behind the wainſcot adjoining the chimney, goes under the floor, and up one of the legs of the harpſichord, into the caſe, and round a ſmall wheel fixed on the axis of that firſt mentioned. There ſhould be pullies at different diſtances, behind the wainſcot and under the floor, to facilitate the motion of the chord.

This machinery may be applied to any other keyed inſtrument, as well as to chimes, and to many other purpoſes where a regular continued motion is required.

An inſtrument of this ſort may be conſidered as a perpetual motion, according to the common acceptation of the term, for it will never ceaſe going till the fire be extinguiſhed, or ſome parts of the machinery be worn out.

RECRE-

RECREATION LIV.

A ventosal symphony.

AT the top of a summer-house, or other building, let there be fixed a vane AB (Pl. XVIII. Fig. 3.) on which is the pinion C, that takes the toothed wheel D, fixed on the axis EF, which at its other end carries the wheel G, that takes the pinion H. All these wheels and pinions are to be between the roof and the cieling of the building. The pinion H is fixed to the perpendicular axis IK, which goes down very near the wall of the room, and may be covered after the same manner as are bell-wires. At the lower end of the axis IK there is a small pinion L, that takes the wheel M, fixed on the axis of the great wheel NO. In this wheel there must be placed a number of stops, corresponding to the tunes it is to play. These stops are to be moveable, that the tunes may be altered at pleasure. Against this wheel there must hang twelve ſmall bells, anſwering to the notes of the gamut. Therefore, as the wheel turns round, the ſtops ſtriking againſt the bells, play the ſeveral tunes. There ſhould be a fly to the great wheel, to regulate its motion when the wind is ſtrong. The wheel N O, and the bells are to be encloſed in a caſe.

There may be ſeveral ſets of bells, one of which may anſwer to the tenor, another to the treble, and a third to the baſe; or they may play different tunes, according to the ſize of the wheel. As the bells are ſmall, if they are of ſilver, their tone will be the more pleaſing.

Inſtead of bells, glaſſes may be here uſed, ſo diſpoſed as to move freely at the ſtroke of the ſtops. This machinery may likewiſe be applied to a barrel-organ; and to many other uſes.

RECRE-

RECREATION LV.

The nocturnal reveilleur.

AGAINST the wall of a room, near the cieling, fix a wheel of 12 or 18 inches diameter; on the rim of which place a number of bells in tune, and, if you pleaſe, of different ſizes. To the axis of this wheel there ſhould be fixed a fly, to regulate its motion; and round the circumference there muſt be wound a rope, to the end of which is hung a weight.

Near to the wheel let a ſtand be fixed, on which is an upright piece that holds a balance or moveable lever, on one end of which reſts the weight juſt mentioned, and to the other end muſt hang an inverted hollow cone, or funnel, the aperture of which is very ſmall. This cone muſt be graduated on the inſide, that the ſand put in may anſwer to the number of hours it is to run. Againſt the upright piece, on the ſide next the cone, there muſt be fixed a check, to prevent it from deſcending. This ſtand, together with the wheel, may be encloſed in a caſe, and ſo contrived as to be moved from one room to another with very little trouble.

It is evident from the conſtruction of this machine, that when a certain quantity of the ſand is run out, the weight will deſcend, and put the wheel in motion, which motion will continue till the weight comes to the ground. If the wheel be required to continue longer in motion, two or more pullies may be added, over which the rope may run.

The ſize of the bells ſhould be adapted to the ſomniferous diſpoſition of the party they are intended to rouze; or, if you pleaſe, a drum or tabor may be added, the

the ſtick to which may be fixed in the ſide of the room, by a ſwivel that goes through the middle of it; and one end of it being lifted up by teeth placed on the circumference of the wheel, the other end will alternately ſtrike the drum.

RECREATION LVI.

A musical cascade.

WHERE there is a natural cascade, near the lower stream, but not in it, let there be placed a large wheel, equal to the breadth of the cascade: the diameter of this wheel, for about a foot from each end, must be much less than that of the middle part; and all the water from the cascade must be made to fall on the ends *. The remaining part of the wheel, which is to be kept free from the water, must consist of bars, on which are placed stops, that strike against bells, as in the 54th Recreation: these stops must likewise be moveable, but larger than in that Recreation, as well as the bells, that they may be heard much further. It is evident

* The water that falls on the wheel may pass thro' pipes, so that part of it may be made occasionally to pass over or fall short of the wheel, as you would have the time of the music quicker or slower.

from

from the conſtruction of this machine, that the water falling on the floats at the ends of the wheel, will make the ſtops, which are adapted to different tunes, ſtrike the notes of thoſe tunes on the reſpective bells. Two or three ſets of bells may here be placed on the ſame line, when the caſcade is ſufficiently wide.

Where there is not a natural caſcade, one may be artificially conſtructed, by raiſing part of the ground, wherever there is a deſcent of water; whether it be a ſtream that ſupplies a reſervoir or fountain, or ſerves domeſtic uſes; or if it be refuſe water that has already ſerved ſome other purpoſe.

RECREATION LVII.

Reverberated sounds.

SOUND, like light, after it has been reflected from several places, may be collected in one point, as into a focus; and it will be there more audible than in any other part, even than at the place from whence it proceeded. On this principle it is that a whispering gallery is constructed.

The form of this gallery must be that of a concave hemisphere *, as ABC (Pl. XVIII. Fig. 4.) and if a low sound or whisper be uttered at A, the vibrations expanding themselves every way will impinge on the points D D D, &c. and from thence be reflected to E E E, and from thence to the points F and G, till at last they all meet

* A cylindric or elliptic arch will answer still better than one that is circular.

in C, where, as we have ſaid, the ſound will be the moſt diſtinctly heard.

Upon this principle alſo it is that the ſpeaking trumpet is formed. For the ſound, in paſſing through the long and narrow part of the tube, is continually reflected from its curved ſide into the axis, and by that mean is prevented from ſpreading till at its exit from the tube, whereby the ſtrength of the ſound is greatly increaſed.

As by the laſt aphoriſm, page 200, the angle of reflected ſound is equal to that of its incidence, if we know the point from which any ſound proceeds, and the place from which it is reflected, we may eaſily find the point in which its echo will be heard.

To hear the echo of one ſyllable, we muſt be at the diſtance of 120 feet from the reflecting ſurface: for two ſyllables, 240 feet; for three ſyllables 360 feet, &c.

For

For when we speak distinctly we scarce pronounce more than three or three syllables and a half in a second; and as by aphorism 13, sound goes 1142 feet in a second, if the distance between the speaker and the reflecting surface were less than 360 feet, the first syllable would be returned before the last was pronounced *, and therefore the echo could not be distinctly heard. The echo in Woodstock Park is said to return 17 syllables in the day, and 20 in the night; for then the air being colder and denser, by aphorism 15, the strength of the sound must be greater. From hence we may determine nearly, the distance of an object that is inaccessible;

* According to the aphorism, the distance should be 380 feet; for the first syllable must go as far as is equal to the time the two last syllables are pronouncing, that is, two-thirds of a second; therefore the distance should be equal to two-thirds of 1142 feet, or $760\frac{2}{3}$, that is, $380\frac{1}{3}$ going and coming. But as some time must be allowed for the reflecting surface to be made to vibrate by the impinging sound, the first distance, 360 feet, will be very near the truth.

ſible; for if an echo of 10 ſyllables be reflected from the ſide of a church or tower, it follows, from what has been ſaid, that the object muſt be 1200 feet diſtant.

The ſame ſound may have ſeveral echoes, if there be ſeveral reflecting ſurfaces ſo diſpoſed as to make it reverberate to the ſame point. Thus a violin, or other inſtrument, when ſounded in a room where there are ſeveral arches of the ſame form, will ſound like a number of violins of the ſame ſize playing in concert: or if the arches be of different forms, there will ſeem to be different inſtruments playing the ſame tune.

RECREATION LVIII.

The converſive ſtatue.

PLACE a concave mirror of about two feet diameter, as A B * (Plate XVIII. Fig. 5.) in a perpendicular direction. The focus of this mirrror may be at 15 or 18 inches diſtance from its ſurface. At the diſtance of about five or ſix feet let there be a partition, in which there is an opening E F, equal to the ſize of the mirror; againſt this opening muſt be placed a picture, painted in water-colours, on a thin cloth, that the ſound may eaſily paſs through it †.

* Both the mirrors here uſed may be of tin or gilt paſteboard, this experiment not requiring ſuch as are very accurate.

† A Recreation of this kind may be performed in a field or garden, between two hedges, in one of which the mirror A B may be placed, and in the other an opening artfully contrived. The more effectually to conceal the cauſe of this illuſion,

Behind the partition, at the diſtance of two or three feet, place another mirror G H, of the ſame ſize as the former, and let it be diametrically oppoſite to it.

At the point C let there be placed the figure of a man ſeated on a pedeſtal, and let his ear be placed exactly in the focus of the firſt mirror; his lower jaw muſt be made to open by a wire, and ſhut by a ſpring; and there may be another wire to move the eyes; theſe wires muſt paſs through the figure, go under the floor, and come up behind the partition.

Let a perſon, properly inſtructed, be placed behind the partition near the mirror. You then propoſe to any one to ſpeak ſoftly to the ſtatue, by putting his

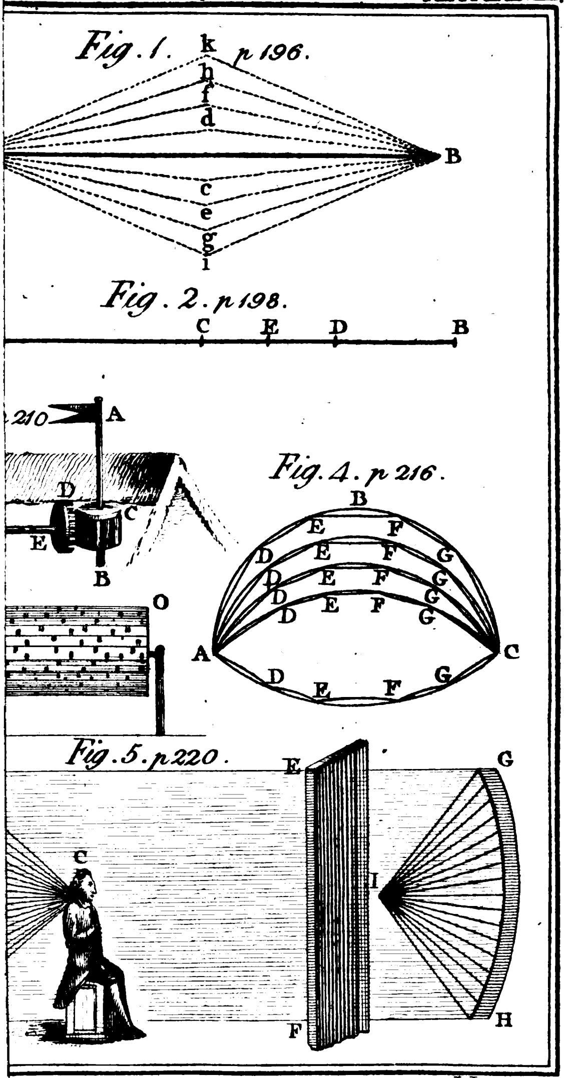
illuſion, the mirror AB may be fixed in the wainſcot, and a gauze, or any other thin covering, thrown over it, as that will not in the leaſt prevent the ſound from being reflected.

mouth

mouth to the ear of it, aſſuring him that it will anſwer inſtantly. You then give the ſignal to the perſon behind the partition, who, by placing his ear to the focus I, of the mirror G H, will hear diſtinctly what the other ſaid, and moving the jaw and eyes of the ſtatue, by the wires, will return an anſwer directly, which will, in like manner be diſtinctly heard by the firſt ſpeaker.

Remark. This Recreatien appears to be taken from the Century of Inventions of the Marquis of Worceſter; one of thoſe men of ſublime genius, who are able to perform actions infinitely ſuperior to the capacity, or even the comprehenſion, of the mere ſcholar or man of buſineſs; and though his deſigns, at the time they were publiſhed, were treated with ridicule and neglect, by the great and little vulgar, who, judging by their own abilities, are ever ready to condemn what they cannot com-

PLATE XVIII.



J. Lodge Sculp.

compehend, yet they are now known to be generally, if not univerſally, practicable. The words of the Marquis are theſe. "How to make a brazen or ſtone head, in the midſt of a great field or garden, ſo artificial and natural, that, though a man ſpeak never ſo ſoftly, and even whiſper into the ear thereof, it will preſently open its mouth, and reſolve the queſtion in French, Latin, Welch, Iriſh, or Engliſh, in good terms, uttering it out of its mouth, and then ſhut it until the next queſtion be aſked."

RECREATION LIX.

The Organ.

THE recreation this inſtrument affords is known to every one; but what we here propoſe is a deſcription of the ſeveral parts of this moſt noble and comprehenſive of all muſical machines, and of the manner by which its numerous ſounds are

are produced: and ſuch a deſcription will, perhaps, afford a perſon of an ingenious diſpoſition a recreation little inferior to the ſounds themſelves.

There are various ſorts of organs, but that we ſhall here deſcribe is the grand, or church organ, which conſiſts of two parts, the main body, called the great organ, and the poſitive or little organ, which forms a ſmall caſe or buffet, commonly placed before the great organ. The ſize of an organ is generally expreſſed by the length of its largeſt pipe: thus they ſay, an organ of 8, 16, 32 feet, &c.*

The ſeveral parts of the church organ are as follow: H I H (Plate XIX. Fig. 1.) is the ſound board, which is compoſed of two parts, the upper board or cover H H H,

* The organ in the cathedral church at Ulm, in Germany, is 93 feet high, and 28 broad: its largeſt pipe is 13 inches diameter, and it has 16 pair of bellows.

and

and the under board H I, which is much thicker than the other; each of theſe conſiſts of ſeveral planks, laid with their edges to each other, and joined very cloſe together. In the under ſide of the lower board there are made ſeveral channels, which run in the direction L L, M M, &c. and are continued as far as there are ſtops in the organ, and come almoſt to the edge H K. Theſe channels are covered over, very cloſe, with parchment or leather, all the way, except a hole that is commonly at the fore end next H K, upon which a valve or puff is placed. Theſe channels are called partitions. When this valve or flap is ſhut it keeps out the air, and admits it when open. On the upper ſide of the lower board there are likewiſe cut ſeveral broad, ſquare channels, lying croſs the former, but not ſo deep as to reach them; theſe lie in the direction L N, P Q, &c. To fit theſe channels there are the ſame number of wooden ſliders or regiſters *f, f, f,* &c. running the whole length; and theſe may be drawn out, or thruſt in, at pleaſure. The number of theſe is the ſame as that of the ſtops in the organ.

IKKK is the wind cheſt, which is a ſquare box, fitted cloſe to the under ſide of the lower board, and made air tight, ſo that no air can get out, but what goes through the valves, along the partitions.

VV are the valves or puffs, which open into the wind-cheſt; they are all incloſed in it, and may be placed in any part of it, as occaſion ſhall require. One of theſe valves, with the ſpring that ſhuts it, and the wire that opens it, is repreſented by Fig. 2.

C, D, E, F, &c. are the keys on which the fingers are placed, when the organ is played: theſe keys lie over the horizontal bar of wood W, in which are ſtuck an equal number of wire pins z, z, on which keys are fixed; and the keys move up and down on the bar, as on a center. There is another bar, againſt which the keys fall when put down, and which is here marked 3: on this alſo are ſeveral wires, which go through the keys, to guide them; and on this bar a lift is faſtened to hinder the keys from knocking againſt the wood.

The keys are made to communicate with the valves ſeveral ways, as we ſhall now deſcribe. Firſt, s, s, s, are the key rollers, moving on the pivots t, t: theſe rollers lie horizontally, one above another, and are of ſuch a length as to reach from the valve to the key: a, a, a, are arms or levers fixed to the key-rollers: w, w, the valve wires fixed to the arms a, a, and to valves V, and go through the holes h, h, in the bottom of the wind-cheſt: b, b, b, are likewise arms fixed to the key-rollers: *d*, *d*, *d*, the key-wires, fixed to the arms *b*, *b*, and to the keys C, D, E. Now when the end of any one of the keys C, D, E, is put down, it pulls down the arm *b*, by the wire *d*, which turns about the roller *s* with the arm *a*, that pulls down the wire *w*, which opens the valve, that is shut by the spring as soon as the pressure is taken off the key. In this construction there must be a worm spring fastened to the key, and to the bar W, on the further side, to keep down the end 5, of the key.

Another method of opening the valves is thus: *xy*, *xy*, are slender levers, moveable on the centers 1, 1: 5 *x*, 5 *x*, are wires going from the further ends of the keys to the ends *x* of the levers: *y* V, *y* V, are other wires, reaching from the ends *y* of the levers, through the holes *h*, to the valves V. So that putting down the key C, D, &c. raises the end 5, which thrusts

8 up

up the end x of the lever, by the wire $5x$; this depresses the end y of the lever, which pulls down the wire yV, and opens the valve V.

A third way of opening the valves is this: at the end of the key b, is a lever 8, 9, moving in the center 7. This makes, with the key, a compound lever. From the end 9, a wire goes to the valve. Now the putting down the end 6 of the key, raises the end 8, which depresses the end 9, of the lever 8, 9, pulls down the wire, and opens the valve. There is only one of these drawn in the scheme, and but a few of the others; to avoid confusion.

R, R, are the rollers, to move the sliders, by help of the arms cf, cf, which are fixed horizontally in these rollers: ke, ke, are also levers fixed in the rollers; le, le, are the handles, which lie horizontally, and pass through the holes l, l; they are faſtened to the lever *k e*, being moveable about a joint at *e*.

Now, any handle *l p*, being drawn out, pulls the end *e* toward *l*, which turns about R *k*, along with the arm *c f*; and the end *f* pulls out the ſlider *f g*; and when *p* is thruſt in, the arm *c f* likewiſe thruſts in the ſlider *f g*.

Upon the ſeveral rows of holes which appear on the top of the upper board, there are ſet up an equal number of rows of pipes. The pipes of an organ are of two kinds, the one has a mouth like a flute, the other with reeds. The firſt, called pipes of mutation, conſiſt (1.) of a foot A A B B (Fig. 3.) which is a hollow cone, that receives the wind that is to ſound the pipe: (2.) to this foot is faſtened the body of the pipe B B D D. Between the foot and the body of the pipe is a diaphragm or partition F E F, that has a long

but

but narrow aperture, by which the wind comes out: over this aperture is the mouth BBC, whofe upper lip C, being level, cuts the wind as it comes out.

The pipes are of pewter; of lead mixed with a twelfth part of tin, and of wood. Thofe of pewter are always open at their extremities: their diameter is very fmall, and their found very clear and fhrill. Thofe of lead mixed with tin are larger: the fhorteft are open, the longeft quite ftopped: thofe of a mean fize are partly ftopped, and have befide a little ear on each fide the mouth, to be drawn clofer or fet further afunder, in order to raife or lower the found. The wooden pipes are fquare, and their extremity is ftopped with a valve or tampion of leather. The found of the wooden and leaden pipes is very foft: the large ones ftopped are commonly of wood, the fmall ones of lead. The longeft pipes give the graveft found, and the fhorteft the moft acute: their lengths and widths are determined by a fixed proportion to their ſounds, and their diviſions are regulated by a rule, which is called the diapaſon. The longeſt has commonly ſixteen feet; but in very large organs it has thirty-two feet. The pedal tubes are always open, though made of wood and of lead. Whatever note any open pipe ſounds, when its mouth is ſtopped, it will ſound an octave lower; and a pipe of twice its capacity will likewiſe ſound an octave lower.

A reed pipe conſiſts of a foot A A BB, (Fig. 4.) that carries the wind into the ſhalot or reed CD, which is a hollow demi-cylinder, fitted, at its extremity D, into a ſort of mould, by a wooden tampion G. The ſhallot is covered with a plate of copper K K L L, fitted, at its extremity I I, into the mould, by the ſame wooden tampion. Its other extremity K K, is at liberty, ſo that the air entering the ſhallot makes it tremble, or ſhake againſt the reed; and the longer that part of the

tongue

tongue I L, which is at liberty, is made, the deeper is the ſound. The mould I I, that ſerves to fix the ſhallot or reed, the tongue, tampion, &c. ſerves alſo to ſtop the foot of the pipe, and make the wind go out wholly at the reed. Laſtly, in the mould is ſoldered the tube H H, whoſe inward opening is a continuation of that of the reed: the form of this tube is different in different ranks of pipes. The degree of acuteneſs or gravity in the ſound of a reed-pipe, depends on the length of the tongue, and that of the pipe CK, taken from the extremity of the ſhallot, to the extremity of the tube. The quantity or intenſion of the ſound depends on the width of the reed, the tongue, and the tube; as alſo on the thickneſs of the tongue, the figure of the tube, and the quantity of wind. To diverſify the ſounds of the pipes, a valve is added to the port-vent, which makes the wind go out in fits or ſhakes. In Fig. 1. X repreſents a flute-pipe of wood, Z a flute-pipe of metal, Y a trum-

pet-

pet-pipe of metal. The pipes, to prevent them from falling, paſs thro' holes made in boards, placed upon the upper board.

The pipes are made to communicate with the wind-cheſt in the following manner. There are holes bored that go thro' the upper and lower boards, and through the ſlider, (when it is drawn out) into the partition below; ſo that any pipes placed upon thoſe holes will then communicate with the partition, which, by its valve, communicates with the wind-cheſt. But when the ſlider is thruſt in, its holes do not anſwer to thoſe in the upper and lower boards, therefore the communication is ſtopped, ſo that no wind can get to the pipe.

To every large organ there muſt be at leaſt two pair of bellows, which are marked in Fig. 1. by 9 T, 9 T. O, O, are the handles, moving upon the axes *n n*, *n n*. Each of theſe

these bellows consists of two boards, the lowest of which is immoveable; and in this there is a valve *r*, opening inwards, and a tube leading to it, called the conveying tube. There is also a hole in this under board, from which a tube leads to the port-vent, which is a square tube marked 4, rising upward, and inserted into the under side of the wind-chest at 2. In the tube leading to the portvent there is a valve that opens toward the port-vent, and suffers the air to go up the port-vent, but not to return. Now the handle O being put down, raises the upper board T, and the air enters through the valve *r*, and when the handle is let go, the weight of the upper board, which carries three or four pound to every square foot, continually descending, drives the air through the port-vent to the sound-board; and as the bellows work alternately, one pair is constantly descending, which occasions a continual blast through the port-vent. In chamber-organs there is but one pair of bellows,

bellows, but they are formed of three boards, in the manner of a ſmith's bellows, and ſo have a continual blaſt. All the internal ſtructure of the organ is concealed from the ſight by the front of the inſtrument, which ſtands upon the part between the numbers 3 and 6 (Fig. 1.)

In every organ the number of partitions L L, M M, &c. there are in the found-board (Fig. 1.) that of the valves V, V; that of the rollers *s*, *s*; or of the levers *x*, *y*, or 8, 9, and their wires: and that of the keys A B C, &c. muſt be always equal. Large organs have commonly four or five ſets of keys, beſide thoſe that belong to the pedals or large pipes, the ſtops to which are played by the feet. The keys of an organ are uſually divided into four octaves, which are, the ſecond ſub-octave, firſt ſub-octave, middle octave, and firſt octave. Each octave is divided into twelve ſtops or frets, of which ſeven are black and five white; the former mark the natural

tural notes, and the latter the artificial notes, that is, flats and ſharps. The number of keys, therefore, when there are four octaves, muſt be 48. Some organiſts add one or more ſtops to the firſt and ſecond ſub-octaves. The pedals have two or three octaves, at the option of the organiſt; ſo that the number of ſtops is indeterminate. The keys are placed between G G, (Fig. 1.) but the ſcheme could not contain them all. There are alſo as many handles *l*, *l*, &c. rollers R, R, &c. ſliders *f*, *f*, &c. as there are ſtops upon the organ; and it muſt be obſerved, that between the ſliders *f*, *f*, &c. there are as many ſliders on the right hand, and the ſame number of handles and rollers, and other rows of pipes placed between L N, P Q, &c. which could not be expreſſed in the figure.

The leaſt pipes and partitions are placed toward the middle of the organ, and the greateſt on the outſide. The ſtops of of an organ have various denominations, according to the ſounds they are to produce; ſome of which are diapaſon, principal, fifteenth, twelfth, tearce, cornet, trumpet, French horn, vox humana, flute, baſſoon, cremona, &c. There is likewiſe a contrivance to ſwell the notes of ſome of the ſtops.

When this magnificent inſtrument is played, the handle O of the bellows is firſt put down, which raiſes the upper board T, and gives room for the air to enter by the valve *r*. Then the other handle O is put down; in the mean time the board T, belonging to the firſt handle, deſcending, and ſhutting the valve *r*, drives the air, through the other valve, up the port-vnet, and into the wind-cheſt. Then drawing out any handle, as that of the flute-ſtop *p l*, which draws out the ſlider *f g*, all the pipes in the ſet L N are ready to play, as ſoon as the keys C, D, E, &c. are put down: therefore, if the key D be put down, it opens

opens the correſponding valve *m* V, thro' which the air enters into the pipe X, and makes it ſound. In the ſame manner any other pipe, in the ſet LN, will ſound when its key is put down; but no pipe, in any other ſet, will ſound, till the ſlider be drawn out by its correſponding handle.

The organ is not only the moſt grand, but the moſt ancient of all compound muſical machines. Vitruvius deſcribes an hydraulic organ in the tenth book of his architecture, which was celebrated by the Emperor Julian, in an epigram. St. Jerome mentions an organ that had twelve pair of bellows, and whoſe ſound might be heard at the diſtance of a mile.

THE

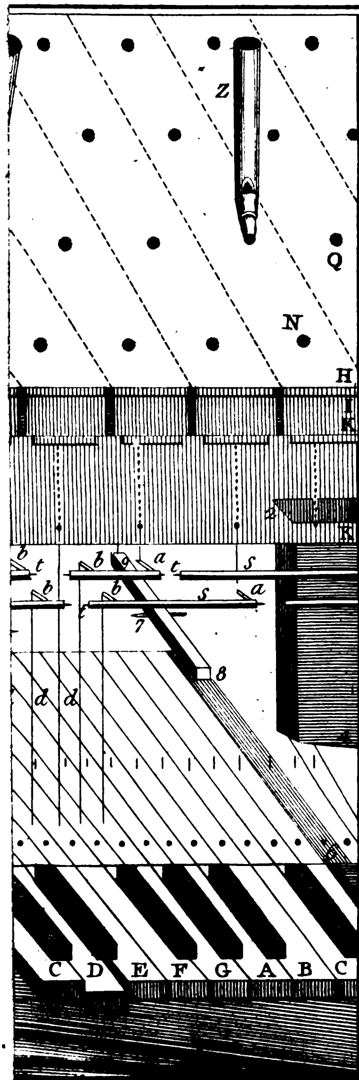


Fig. 2. p. 226.

Fig. 3. p. 230.

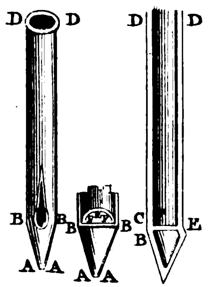
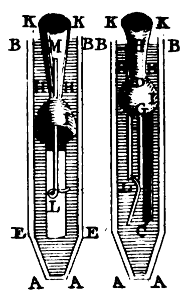


Fig. 4. p. 232.



J. Lodge Sculp.

THE

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RECREATION I. p. 14.

Optical illusion.

Three pieces of money being placed in a vessel (Pl. III. Fig. 1.) out of the view of a spectator, and water being poured into the vessel all those pieces become visible—by the refraction of the light thro' the water.

RECREATION II. p. 15.

Optical augmentation.

A shilling being put in a glass of water, and a plate placed upon it, the glass is turned over with the plate, and there appears a half crown on the plate and a shilling over it—by the seeing the shilling through the top and the side of the water at the same time, and the different refraction of the light.

RECRE-

RECREATION III. p. 17

Optical subtraction.

Three small pieces of paper being placed against a wall, (Plate III. Fig. 2.) a person by shutting one of his eyes can see only two of them—the rays that come from one of the pieces falling always on the optic nerve, and not on the retina.

RECREATION IV. p. 18

Alternate illusion.

A silver seal, when viewed through a convex lens, appears alternately engraved and in relief—conjecture on the cause of this remarkable phenomenon p. 90 (note)

RECREATION V. p. 20

The camera obscura.

A convex lens is placed in the window-shutter of a dark room, and a concave paſteboard, lined with white paper, is placed in the focus of the lens, whereby the objects without the room are painted on the paper, but inverted—method of making them appear erect, page 22 (note)—this apparatus improved by a mirror placed in different poſitions, p. 22—preſents the moſt pleaſing and natural of all pictures 25

RECREATON VI. p. 25

To ſhow the ſpots in the ſun's diſk, by its image in the camera obſcura.

By placing a ſcioptric ball, that is, a ball of wood in which a lens is fixed, oppoſite the ſun, which will throw its image on the paper—this image to be viewed through another lens, p. 26

RE-

RECREATION VII. p. 27

To magnify ſmall objects by means of the ſun's rays let into a dark chamber.

By throwing the rays on a concave mirror, and holding the ſmall objects, ſtuck on ſlips of glaſs, near the focus of the mirror, by which mean their images are reflected on the wall.

RECREATION VIII. p. 28

The portable camera obſcura.

A plate of glaſs is placed in a horizontal frame of wood that is ſupported by four legs, which fold up (Plate III. Fig. 3.) Under the frame is a box, that likewiſe folds up, and at the bottom of it are a tube and a mirror, by which the objects are reflected to the glaſs—advantage of this camera over others, p. 30—manner of drawing object by this machine p. 31

RECREATION IX. p. 32

The magic lantern.

The origin of this machine—it consists of a tin box, at one end of which is a concave mirror; in the other end is fixed a lens, and between them is placed a lamp: before the lens is fixed a square tin tube in which there is a groove, and through this groove the glasses that contain the objects are passed; in this tube is placed another, that is moveable, and contains two lenses, which throw the objects on a cloth—method of painting the glasses, p. 37—proposal of improving this machine by using moveable objects p. 39

RECREATION X. p. 40

To represent a tempest by the magic lantern.

By passing two glasses, on one of which is painted the sea and sky, and on the other

other ſhips, (Plate IV. Fig. 1 and 2.) through the groove at the ſame time, and giving them a proper motion—by the ſame method a battle, and many other ſubjects may be exhibited p. 42

RECREATION XI. p. 43

The nebulous magic lantern.

At the bottom of a ſquare box, whoſe height is equal to ſix times its width, (Plate IV. Fig. 3.) is placed a chafing-diſh of hot coals, on which incenſe is burnt, and on the ſmoke that comes out of the top of the box is thrown the figures of the magic lantern.

RECREATION XII. p. 44

To produce the appearance of a phantom, on a box or pedeſtal placed on a table.

A common magic lantern is placed in a box, (Plate IV. Fig. 4.) in which there is an inclined mirror, that reflects the light of the lantern on the thick ſmoke of a chafingdiſh of coals placed on the box, and ſhows the image reflected by the glaſs—this Recreation muſt be performed in a dark room p. 47

RECREATION XIII. p. 48

The magical theatre.

A magic lantern muſt be provided that has a tube in two of its oppoſite ſides, (Pl. IV. Fig. 5.) in one of which tubes there muſt be ſeveral grooves, by which the ſubjects to be repreſented may be paſſed either horizontally, aſcending, or deſcending, and two or more of them at the ſame time. In the partition between the room where the lantern is, and that where the exhibition is to be ſeen, there muſt be placed a glaſs, covered with thin paper, on which the objects are to be thrown—example of a repreſentation of the ſiege of Troy, in five acts, p. 52—it is quite neceſſary that the glaſſes

glaſſes for theſe exhibitions be accurately painted, p. 60

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Properties of plain mirrors, p. 63—of ſpherical convex mirrors, p. 64—of ſpherical concave mirrors, p. 65.

RECREATION XIV. p. 67

The boundleſs gallery.

Againſt each of the two ſmalleſt ends of an oblong box (Plate VI. Fig. 1.) is placed a plain mirror, and from one of them the quickſilver is taken off for the ſpace of an inch and a half, oppoſite which a hole is made in the box: the top of the box is covered with glaſs, and between the mirrors are placed ſcenes properly painted, which when viewed from the hole at the end of the

6 box,

of a dial case, and toward the top of the case is fixed a mirror, by which the figures of the hours are reflected to the part where the dial is commonly seen. Another dial plate, at the back of which is concealed an artificial magnet, that is moved by the hand of that dial, is given to a person, who setting the hand privately to any hour, puts it in a drawer at the bottom of the dial-case, under the first mentioned dial, and looking in at top he sees the reflection of the dial there, answer to the hour at which he set the other dial; the hand of the first being moved, by the attraction of the magnet in the other, to the same hour.

RECREATION XIX. p. 81

The box of divination.

A box that contains four cases, on each of which a number is wrote, and at the bottom of which a magnet is concealed,

Plate

(Plate VIII. Fig. 1.) is placed on a table: under that part of the table are placed four moveable circles, that have each a needle, and under them is a drawer, that contains a mirror, so that by looking into the drawer you see, by that mirror, in what order are placed the boxes that have the numbers.

RECREATION XX. p. 84

The magical perspective.

A small common perspective (Plate VIII. Fig. 6.) is fixed on a hollow stand of wood; in this perspective is placed a mirror, which is moved by the inner tube, so as to show any object under the hollow stand. Three of these perspectives are set over three holes in the top of a box, (Fig. 5.) at the bottom of which is placed a moveable circle, that is divided into twenty-one equal parts, and contains a magnetic needle: this box is set on a table, under which

is

is concealed a magnetic bar, that being privately placed in any poſition, determines that of the circle in the box, and conſequently brings any of the objects painted on it under the ſeveral perſpectives.

RECREATION XXI. p. 93

The penetrative perſpective.

In a box or caſe that has two prominent parts or arms, (Plate X. Fig. 1.) are placed four mirrors, and in each of the arms is fixed the tube of a perſpective glaſs, ſo that the object next the end of one perſpective, being reflected by the four mirrors, is ſeen at the end of the other, and appears as if viewed through the two perſpectives, and conſequently is perfectly viſible when an opaque body is placed between thoſe two perſpectives.

RECREATION XXII. p. 96

The magician's mirrors.

Two glaſſes are fixed in the partition of a room, at about a foot diſtant from each other: (Plate X. Fig. 2.) behind theſe glaſſes are placed two mirrors, inclined in a proper angle, ſo that a perſon looking into one of them, inſtead of ſeeing his own face, ſees that of another perſon who at the ſame time looks into the other glaſs. Method of improving this Recreation, by putting the two glaſſes in adjoining rooms, p. 97—properties of plain mirrors when placed in different poſitions p. 98

RECREATION XXIII. p. 100

Polimoſcopes.

Theſe inſtruments conſiſt of a tube that contains an inclined mirror, and has an eye-

eye-glaſs of a proper focus, ſo that while the tube is pointed at one object you ſee another. By placing an inſtrument of this ſort at the top of a wall; while you ſtand at the bottom, you ſee what paſſes on the other ſide, p. 161

RECREATION XXIV. 102

The enchanted mirrors.

In four parallel ſides of a cubical box are fixed four glaſſes, repreſenting mirrors, and within the box are placed two mirrors, that croſs it diagonally. When four perſons look into the glaſſes, each of them ſees, inſtead of his own face, that of the perſon next him, and who appears at the ſame time to be placed directly oppoſite to him.

RECREATION XXV. p. 103

The animated optic balls.

This pleasing piece of optics consists of an oblong box, (Pl. IX. Fig. 2.) three fourths of the upper part of which is divided from the lower by a horizontal partition, and is decorated with paintings. In the lower part of the remaining fourth is placed an inclined plane, in the middle of which is a serpentine groove, and in the other parts are paintings, or objects in relief: in the upper part of this space is a mirror, placed in in a proper angle to reflect the objects on the plane. At the end of the box is a small opening, by which ivory balls, that may be painted with different colours, are put in, and running down the groove in the inclined plane, pass out at the bottom, and are raised to the same opening again by a machine placed there

there for that purpofe. Part of the top of this box is covered with glafs, lined with gauze, and near the inclined plane is placed a lamp. In the end of the box, oppofite the plane, there is an opening, in which a glafs is fixed, and thro' which the objects on the inclined plane are feen, reflected by the mirror, and being all inverted, the balls feem to roll up the mirror, and pafs out at the top of the box.

RECREATION XXVI. p. 111

The optic balls by a double reflection.

This box differs from the laft in having a mirror where the inclined plane is there placed, and in the planes being placed at the oppofite end of the box. There may alfo be an additional number of grooves, with a fmall inclination, thro' which the balls may pafs: and if there be fufficient room, there may be two fets of grooves, by which the balls will feem in the mirror to rencounter and pafs over each other.

RECRE-

RECREATION XXVII. p. 114

To describe on a plain surface an irregular figure, which shall appear regular when placed opposite a multiplying glass, and and seen, by reflection, through an aperture made in the center of the drawing.

The plan of the multiplying glass (Plate X. Fig. 5.) being drawn on paper, the design is to be drawn on that. The glass is to be fixed on a stand at one end of a box, and at the other end is to be a frame that holds a paper, in the middle of which is a hole, and on which is to be transferred the design drawn on the multiplying glass, and which will then be quite distorted; but being seen in the mirror, by looking through the hole, it will appear quite regular.

RECREATION XXVIII. p. 120

To describe, on a plain surface, a deformed figure, which shall appear regular when viewed by reflection in a cylindrical mirror.

Part of the surface of the cylinder (Pl. XI. Fig. 1.) is to be divided by lines, into twelve parts, in proportion to those of the diameter of the circle CD, Fig. 2. The parallelogram, Fig. 3. is likewise to be divided into twelve equal parts, and on them a regular figure is to be drawn, and then transferred to the same number of parts, which will be reflected on the plane DG, by the lines on the cylinder, and the figure will then appear deformed, but being seen from the point of view E, will be quite regular. A similar experiment may be made with prismatic and other mirrors p. 124

RECREATION XXIX. p. 123

Optical appearances.

A bottle half full of water being placed near the focus of a concave mirror, appears not only inverted, but the water at the top of the bottle and the bottom of the bottle empty. If the bottle be inverted and placed before the mirror, its image will appear erect, and the water at the bottom of the bottle. If while the bottle is inverted it be uncorked, it will appear, that while the upper part is emptying the bottom part is filling.

RECREATION XXX. p. 128

The perspective mirror.

At one end of an oblong box (Plate XII. Fig. 1.) is placed a concave mirror; near the upper part of the opposite end a hole is made, and about the middle of the box is placed a hollow frame of

paſteboard, that confines the view of the mirror. The top of the box next that end in which the hole is made is covered with a glaſs; and under the hole are placed, in ſucceſſion, different pictures, properly painted, which are thrown into perſpective by the mirror, and produce an appearance that is highly pleaſing.

RECREATION XXXI. p. 130

To ſet fire to a combuſtible body by the reflection of two concave mirrors.

These two mirrors (Plate XII. Fig. 2.) are placed at a conſiderable diſtance, and in the focus of one of them is put a live coal, in that of the other ſome gunpowder, and by the blowing on the coal, the gunpowder will take fire, though the diſtance between the mirrors be ſeveral feet.

RE-

RECREATION XXXII. p. 132

The real apparition.

A hole is made in a partition, (Plate XIV. Fig. 3.) and behind it is placed a large concave mirror, and a ſtrong light, that muſt not be viſible at the hole. On the ſame ſide of the partition, and directly under the hole, is fixed, in an inverted poſition, the object that is to appear without the partition. A perſon being placed in a proper point of view will ſee the object on the outſide, and in an erect poſition—The figure of an abſent or deceaſed friend may be made to appear by this method, p. 134—The imaginary combat by a concave mirror, p. 136

CHROMATICS.

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RECREATION XXXIII. p. 140

Out of a ſingle colourleſs ray of light to produce ſeven other rays, which ſhall paint, on a white body, the ſeven primary colours of nature.

A round hole is made in the window-ſhutter of a dark room, and the ray of light that enters at the hole, falling on a priſm, is refracted, and being thrown on a paper placed at a proper diſtance, forms an oblong ſpectrum that exhibits all the primary colours of nature.

RECREATION XXXIV. p. 142

From two or more of the primary colours to compoſe others, that ſhall, in appearance, reſemble thoſe of the priſm.

By mixing any two of the primary colours, as yellow and blue, the intermediate colour, green, will be formed; but theſe mixed colours, though ſimilar in appearance to the primary, yet when viewed

viewed through a priſm, are reſolved into the colours of which they are compoſed.

RECREATION XXXV. p. 144

Out of the three primary colours, red, yellow, and blue, to produce all the other priſmatic colours, and all that are intermediate to them.

Three panes of glaſs are divided, each of them into five equal parts, and over thoſe parts are paſted a different number of papers, painted either red, yellow, or blue (Pl. XIII. Fig. 2.) When one of theſe glaſſes is put in a box, open at two oppoſite ends, all the gradations of the colour it contains are viſible; and when two of them are placed together, Fig. 3, the intermediate colour appears, with its ſeveral degrees.

RECREATION XXXVI. p. 147

By means of the three primary colours, red, yellow, and blue, together with light and

ſhade, to produce all the gradations of the priſmatic colours.

On ſeven ſquare panes of glaſs papers are paſted that contain all the priſmatic colours, and over them are put a different number of pieces, tinged with a deep ſhade, and they are then placed in a box, in the ſame manner as in the laſt Recreation. Method of printing in colours, p. 148.

RECREATION XXXVII. p. 150

The magical priſm.

A ray of light that comes through a hole made in the window-ſhutter of a dark chamber, falling on a glaſs priſm, (Plate XIII. Fig. 4.) is refracted on a hollow priſm of wood, that revolves on an axis, and in whoſe ſides figures are cut. As this priſm changes its poſition with regard to that of the glaſs, the figures cut out will appear white, yellow and red, or blue and violet.

RE-

RECREATION XXXVIII. p. 152

The solar magic lantern.

A small box that is open at two opposite sides, is placed against a hole of the same size in the window-shutter of a dark chamber that faces the sun. Thro' this box are passed, by a groove, pasteboard blacked, and through which different figures are cut. These figures, when viewed through a prism, appear to be painted with the most lively colours in nature. This Recreation may be diversified by pasting papers, tinged with different colours, over the figures in the pasteboard.

RECREATION XXXIX. p. 154

The artificial rainbow.

Opposite a window on which the sun shines, a glass globe, filled with water, is suspended by a string that passes over a pulley; and when it is drawn up to a certain height, which may be found by trial,

trial, the colours of the rainbow will appear in it: when it is drawn up a little higher the colours disappear, and when it is drawn up still higher they appear again, and at last totally disappear. The phenomena of the natural rainbow explained by this experiment, p. 155.

RECREATION XL. p. 158
The prismatic camera obscura.

Two holes are made in the shutter of a dark chamber, (Plate XIII. Fig. 5.) and against each of them a prism is placed, in such manner that both their spectrums are cast upon the same spot. Several papers, of the same dimension with the spectrums, have lines drawn on them, parallel to the divisions of the colours, and between those divisions figures are cut out, which then appear to be painted with all the primary colours. This Recreation may be diversified by turning one of the prisms round; and by looking at the spectrums through another prism, p. 159.

RE-

RECREATION XLI. p. 160

The diatonic ſcale of colours.

The ſun's ſpectrum is to be largely refracted on a paper, and the diviſions of the ſeveral colours ſet off, when they will be found to correſpond to the diviſions of a muſical chord for the notes of an octave.

RECREATION XLII. p. 162

Colorific muſic.

The ſurface of a hollow cylinder (Plate XIV. Fig. 2.) is divided vertically into ſix equal parts, and horizontally into forty-one parts; in each of the latter parts ſpaces are cut, over which are paſted papers that are painted with the ſeven primary colours. At the bottom of this cylinder is a wheel, an endleſs ſcrew, and a nut; and when it is placed in a caſe, Fig. 3, the endleſs ſcrew is turned

turned by a handle, which turns the wheel, and raiſes the cylinder by means of the nut at bottom, the height of five of its horizontal diviſions, and conſequently ſhows the ſeveral colours it contains at the eight apertures made in the front of the caſe. A lamp is ſuſpended from the top of the caſe, which, hanging within the cylinder, ſhows the colours that anſwer to the notes of muſic, and the length of thoſe colours correſponds to the duration of the notes.

PERSPECTIVE RECREATIONS.

RECREATION XLIII. p. 168

To draw on a plain ſurface an irregular figure, which, when ſeen from a proper point of view, will appear ſimilar to a given figure.

A parallelogram is divided into forty-eight equal parts, (Plate XV. Fig. 1.) on which the regular figure is drawn, and its

its ſeveral parts tranſpoſed, to an equal number of diviſions in a trapezium, where the figure will appear deformed, but when ſeen from a proper point of view, quite regular. The correſponding parts in the parallelogram and trapezium are to be numbered, p. 172— Theſe figures appear to great advantage when painted on the ſide of a gallery, p. 174.

RECREATION XLIV. p. 175

To draw an irregular figure on a plane, which being ſeen from two oppoſite points of view, ſhall repreſent two different regular objects.

The two regular figures are to be firſt drawn on the two parallelograms, (Pl. XVI. Fig. 3.) and then transferred to the diviſions of the parallelogram, Fig. 2. On a board, Fig. 4, of the ſame ſize with the laſt figure, lines are cut, in which

which a paper, Fig. 5, is pasted, and the distorted figure on it; which when seen from two proper points of view, will present two regular figures.

RECREATION XLV. p. 181.

To draw on the base of a cone an irregular figure, which shall appear, when seen from a proper point of view, not only regular, but elevated above the surface of the cone.

The cone is placed in a board, (Pl. XVII. Fig. 1.) with its base upward, and at one end of it is fixed a perpendicular plate of glass, on which the regular figure is drawn. At the point of view a lamp is placed, by which the figure on the glass is thrown on the base of the cone, and there traced. The lamp and glass are then taken away, and the distorted figure, when seen from the point of view appears not only regular, but erect,

erect, and in the ſame ſituation it was on the glaſs.

RECREATION XLVI. p. 186

To draw, eaſily and correctly, a landſcape, or any other object, without being obliged to obſerve the rules of perſpective, and without the aid of the camera obſcura.

In the largeſt end of a box (Plate XVII. Fig. 3.) there is a frame, divided into a number of equal diviſions, and in the oppoſite end is a tube. This box is ſupported on a ſtand. You are provided with a paper that has the ſame number of diviſions as the frame in the box, and looking through the tube you tranſfer the ſeveral objects ſeen through the diviſions of the frame to thoſe on the paper.

RECREATION XLVII. p. 189

Illuminated proſpects.

The top of a print, properly painted, is cut off, and put in a frame, and the lower part in another frame. Theſe two frames

are placed in a box, (Pl. XVII. Fig. 5.) at different diſtances, and behind them lights are ſet, and when they are viewed from the front of the box, and there is no other light in the room, they afford a very pleaſing appearance.

RECREATION XLVIII. p. 191

Tranſparent illuminations.

Thoſe parts of a print where the light is to appear are cut through with a fine tool. The print is then put in a frame and placed in the box deſcribed in the laſt recreation : behind it is a yellow tranſparent paper, and behind that are lights. Theſe ſcenes are to be moveable, ſo as to repreſent a ſucceſſion of objects differently illuminated.

ACOUSTICS.

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Nature of ſonorous bodies, aph. 1 to 5.—Vibrations of chords, aph. 6 to 9.—Propagation of ſound, aph. 10 to 14.—Strength and reflection of ſound, aph. 15 and 16.

RE-

RECREATION XLIX. p. 201

The eolipiles.

A small metal globe, with a slender neck, is thrown, when hot, into a vessel of water, and when it is put on a fire the water rushes out with a great noise—this phenomenon improved by fixing the calls used by fowlers to the necks of these eolipiles.

RECREATION L. p. 202

The communicative busts.

Two busts are placed on pedestals on the opposite sides of a room, and from the mouth of the one there goes a tube under the floor, to the ear of the other. Therefore, if a person speak into the ear of one bust, another person, who applies his ear to the mouth of the other bust, will hear distinctly all the first utters; and at the same time other people, in the middle of the room, will hear nothing of what passes.

RECREATION LI. p. 203

The oracular head.

This recreation is performed by a ſingle head, and tubes, that go from the ear and mouth of it, to a room underneath, where a confederate hears what is ſaid, and returns an anſwer; and there are wires by which the eyes and lips of the buſt are moved at the ſame time.

RECREATION LII. p. 204

The ſolar ſonata.

A barrel organ is placed in a caſe, that has a glaſs front, behind which is a tube with ſpirits, and on that a cork floats, which, when it riſes to a certain point, by the heat of the ſun, lifts up a catch, and ſets the organ in play; but when the machine is carried into the cold the ſpirits ſink, and the catch again ſtops the organ.

RECREATION LIII. p. 207

An automatous harpſichord.

There are wires that go from the under part of the keys of a harpſichord, and a

barrel

barrel with pins, that take the ends of thoſe wires. Round the axis of the barrel goes a ſtring, that paſſes under the floor, and communicates with a ſmoke-jack, by which the harpſichord is played inceſſantly.

RECREATION LIV. p. 209

A ventoſal ſymphony.

On the top of a houſe there is a vane, (Pl. XVIII. Fig. 3.) at the bottom of which, and within the roof of the houſe, is a wheel, that communicates, by other ſmall wheels and pinions, with a large barrel in the room underneath: to this barrel a number of ſtops are fixed, and cloſe to it are hung twelve bells; therefore, as the vane is turned by the wind, the ſeveral ſmall wheels being put in motion, turn the barrel, and by making it ſtrike the bells, according to the poſition of the ſtops, play the ſymphony.

RECRE-

RECREATION LV. p. 211

The nocturnal reveilleur.

On the circumference of a wheel are placed a number of bells, and round its axis is wound a rope, at the end of which is fastened a weight, that rests upon one end of a moveable lever, and is balanced by a hollow cone filled with sand, hung to the other end of the lever, but as the sand runs out the weight descends, and by turning the wheel rings the bells.

RECREATION LVI. p. 214

A musical cascade.

A large wheel is placed under a cascade, the water of which is confined to the ends of the wheel; the middle of this wheel consists of bars, in which stops are placed, that by striking a certain number of bells play one or more tunes, at pleasure.

RECREATION LVII. p. 216

Reverberated sounds.

Construction of a whispering gallery—the nature of echoes, p. 217—of reverberated echoes, p. 219.

RECREATION LVIII. p. 220

The converſive ſtatue.

There are two large concave mirrors, and in the focus of one of them is placed the figure of a man (Pl. XVIII. Fig. 5.) The other mirror is placed behind a partition, in which is an opening, concealed by a gauze. When a perſon ſpeaks ſoftly in the ear of the ſtatue, which is exactly in the focus of one of the mirrors, another perſon placing his ear in the focus of the other mirror will hear diſtinctly what is ſaid, and anſwering ſoftly at the ſame point will be heard by the firſt perſon.

RECREATION LIX. p. 223

The great organ.

The body of this noble inſtrument conſiſts of a wind-cheſt, (Pl. XIX. Fig. 1.) over which is placed two boards, that form what is called the ſound-board. In the under ſide of the lower board are ſeveral partitions, and in its upper ſide are

are cut channels, in which ſliders are placed, in a tranſverſe poſition to the partitions. There are holes made thro' the upper board, ſliders, and under board, into the partitions; and in the holes of the upper board the pipes are placed that produce the ſounds. There are two pair of bellows, by which the air is forced into the cheſt. When any one of the ſliders is drawn out, its holes correſpond with thoſe in the upper board and in the partitions. At the front end of each partition is a valve, under which is a hole into the wind-cheſt: theſe valves are connected with the keys of the organ by wires, ſo that when a key is put down it opens a valve, and the air ruſhes into the partition, and the ſlider being drawn out, it paſſes through the holes in that and the upper board into the pipe placed over it, and makes it ſound.

THE END OF THE SECOND VOLUME.