22. Two pendulums at the Cape of Good Hope vibrate respectively in 40 seconds and 10 seconds; how many times longer is the one than the other?
23. Two pendulums at New Orleans vibrate in 40 seconds and 10 seconds; how many times longer is one than the other?
24. In the latitude of New York, a pendulum vibrating seconds is $39\frac{1}{10}$ inches in length; how long must one be, to vibrate once in 10 seconds? —*Ans.* 3,910 *inches.*
How long must one be, to vibrate 4 times in a second at the same place? —*Ans.* $2\frac{71}{160}$ *inches.*
25. At the equator, a pendulum 39 inches long vibrates once in a second; how long must a pendulum be, to vibrate once in half an hour at the same place?
How long must one be, to vibrate 10 times in a second?
26. At Trinidad, a seconds-pendulum must be about $39\frac{1}{50}$ inches long; what would be the length of one that would vibrate 3 times in a second?
What would be the length of one that would vibrate 3 times in a minute?
What would be the length of one that would vibrate 3 times in an hour?

CHAPTER VI.

MECHANICS (CONTINUED).

CENTRE OF GRAVITY.

148. The Centre of Gravity of a body is that point about which all its parts are balanced.

The centre of gravity is nothing more than the centre of weight. Cut a body of uniform density in two, by a plane passed in any direction through its centre of gravity, and the parts thus formed will weigh exactly the same. The whole weight of a body may be regarded as concentrated in its centre of gravity.

149. The Centre of Gravity must be carefully distinguished from the Centre of Magnitude and the Centre of Motion.

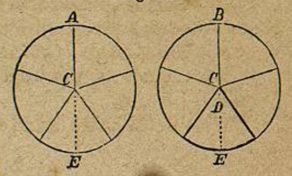
148. What is the Centre of Gravity? How may we divide a body of uniform density into two parts of equal weight? Where may we regard the whole weight of a body as concentrated? 149. From what must the centre of gravity be carefully

150. The Centre of Magnitude (or, as we briefly call it, the Centre) of a body, is a point equally distant from its opposite sides.

151. The Centre of Motion in a revolving surface is a point which remains at rest, while all the other points of the surface are in motion.

In all revolving bodies, a number of points remain at rest. The line connecting them is called the Axis of Motion, or briefly, the Axis of the body.

Fig. 56.



152. The centre of gravity may coincide with the centre of magnitude and lie in the axis of motion, but need not do so. In Fig. 56, A represents a wheel entirely of wood of uniform density; here the centre of gravity coincides with the centre of magnitude, C, and both lie in the axis of motion. B represents the same wheel with its two lower spokes and part of the felly of lead. The centre of magnitude, C, still lies in the axis, but the centre of gravity has fallen to D.

When a body is of uniform density, its centre of gravity coincides with its centre of magnitude. When one part of a body is heavier than another, the centre of gravity lies nearer the heavier part.

153. A line drawn perpendicularly downward from the centre of gravity is called the Line of Direction. In Fig. 56, C E and D E are the Lines of Direction.

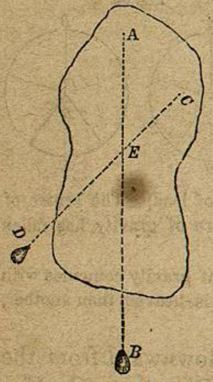
154. How to find the Centre of Gravity.—The part of a body in which the centre of gravity is situated, may be found, in some cases, by balancing it on a point. Thus the centre of gravity of the poker represented in Fig. 57 lies directly over the point on which it is balanced.

Fig. 57.

155. In a solid of regular

distinguished? 150. What is the Centre of Magnitude? 151. What is the Centre of Motion? What is the Axis of a revolving sphere? 152. Show, with Fig. 56, how the centre of gravity may not coincide with the centre of magnitude, or lie in the axis. When does a body's centre of gravity coincide with its centre of magnitude? When one part is heavier than another, where does the centre of gravity lie? 153. What shape and uniform thickness and density, so thin that it may be regarded as a mere surface, such as a piece of pasteboard, the centre of gravity may be found by ascertaining any two straight lines drawn from side to side that will divide it into two equal parts. The point at which these lines intersect is the centre of gravity. Thus, in a parallelogram, the centre of gravity is the point at which its two diagonals intersect.

Fig. 58.

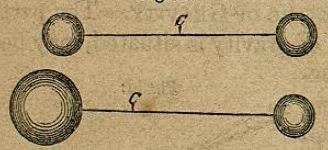


When such a surface is irregular in shape, suspend it at any point, so that it may move freely, and when it has come to rest, drop a plumb-line from the point of suspension and mark its direction on the surface. Do the same at any other point, and the centre of gravity will lie where the two lines intersect.

Thus, suspend the irregular body represented in Fig. 58 at the point A; and, dropping the plumb-line A B, mark its direction on the surface. Then suspend it at C; drop the plumb-line C D, and mark its direction. The lines cross at E, and there will be the centre of gravity.

156. When two bodies of equal weight are connected by a rod, the centre of gravity will be in the centre of the rod. When two bodies of unequal weight are so connected, the centre of gravity will be nearer to the heavier one. These principles are illustrated in Fig. 59, in which C represents the centre of gravity.

Fig. 59.



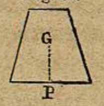
157. Stability of Bodies.—The Base of a body is its lowest side. When a body is supported on legs, like a

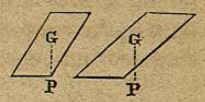
is the Line of Direction? 154. In some bodies, how may the part in which the centre of gravity lies be found? 155. How may the centre of gravity be found, in a thin solid body of regular shape and uniform thickness and density? How may it be found in such a solid, when the shape is irregular? Explain the process with Fig. 58. 156. When two bodies of equal weight are connected by a rod, where does the centre of gravity lie? How does it lie, when the bodies are of unequal weight? 157. What

chair, its base is formed by lines connecting the bottoms of its legs.

158. When the line of direction falls within the base, a body stands; when not, it falls.

Fig. 60. Fig. 61. Fig. 62.





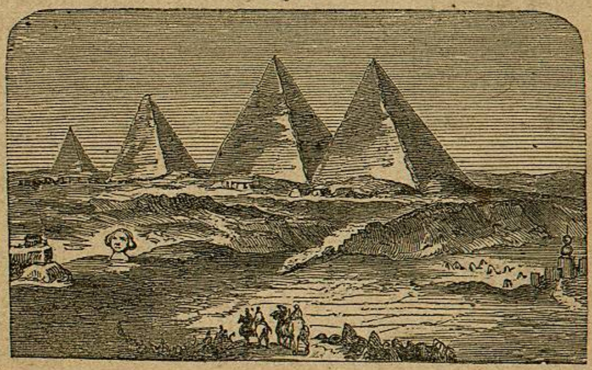
In Fig. 60, G is the centre of gravity; since the line of direction, G P, falls within the base, the body will stand. In Fig. 61, the line of direction falls exactly at one extremity of the base, and the body will be overturned by the slightest force. In Fig. 62, the line of direction falls outside of the base, and the body will fall.

A man carrying a load on his back naturally bends forward, to bring his line of direction within the base formed by his feet. Otherwise, the line of direction falls outside of the base, as shown in Fig. 63; and the load, if heavy, may pull him over backward.

Fig. 63.

159. Of different bodies of the same height, that which has the broadest base is the hardest to overturn, because its line of direction must be moved the farthest to fall outside of its

Fig. 64.



EGYPTIAN PYRAMIDS.

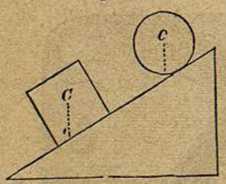
is the Base of a body? When a body is supported on legs, how is its base formed? 158. How must the line of direction fall, for a body to stand? Illustrate this with Figs. 60, 61, 62. What position does a man carrying a load on his back assume, and why? 159. Of different bodies equally high, which is the hardest to overturn?

base. Hence a pyramid is the most stable of all figures; and, of different pyramids of the same height, that which has the broadest base is the most stable. The pyramids of Egypt have withstood the storms of more than three thousand years.

The stability of stone walls is increased by making them broader at the base than at the top. Candlesticks and inkstands generally spread out at the bottom that they may not be easily upset. For the same reason, the legs of chairs bend outward as they approach the floor. A three-legged stool or table has a smaller base than one that has four legs, and is therefore more easily upset. Hence, also, the ease with which a man standing on one leg is overturned.

160. A ball of uniform density has its centre of gravity at its centre of magnitude. When such a ball rests on a level surface, the line of direction falls on the point of support, and it therefore remains in any position in which it is placed. But, as the base of a ball consists of a single point,—the point in which it touches a level surface,—a slight push throws the line of direction beyond the base, and causes the ball to roll.

Fig. 65.



161. When a ball is placed on a sloping surface, the line of direction falls outside of the base, and the ball begins to roll. A cube placed on the same sloping surface maintains its position, because the line of direction falls within its base. See Fig. 65, in which C represents the centre of gravity.

162. Of different bodies with bases equally large, the lowest is the hardest to overturn, because its line of direction is least liable to fall outside of its base.

Why? What is the most stable of all figures? How long have the pyramids of Egypt stood? Give some familiar instances in which the base of a body is made larger than the top, to increase its stability. Why are three-legged chairs and tables easily overturned? 160. In a ball of uniform density, where is the centre of gravity? What is said of the stability of such a ball, when resting on a level surface? 161. When such a ball is placed on a sloping surface, what takes place? Compare it, in this respect, with a cube. 162. Of different bodies with bases equally large, which is the

This is apparent from Figs. 66 and 67. The unfinished tower, though leaning far over, maintains its upright position, the line of direction falling within the base. When made higher by the addition of several stories, as shown in Fig. 67, it will fall, because the centre of gravity has been raised, and the line of direction now falls outside of the base.

Fig. 66.

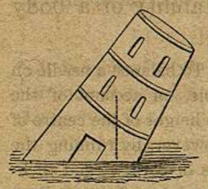
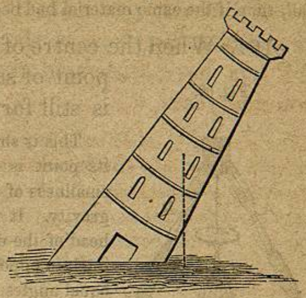
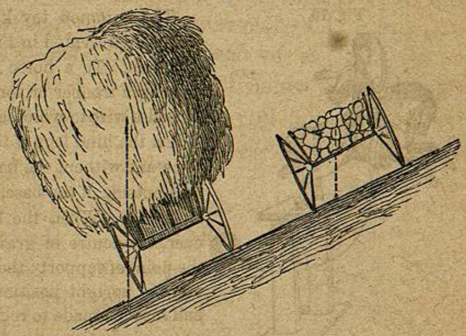


Fig. 67.



High chairs for children are unsafe, unless their legs spread at the bottom. A coach with heavy baggage piled on its top is in danger of upsetting on a rough road. On the same principle, a load of stone may pass safely over a hill-side, on which a load of hay would be overturned. Fig. 68 shows that the line of direction in the one case would fall within the base, while in the other it would fall outside of it.

Fig. 68.



163. The lower its centre of gravity, the more stable a body is. Those, therefore, who pack goods in wagons or vessels, should place the heaviest lowest.

This principle has been turned to account in building leaning towers. The tower of Pisa, which is the most remarkable of these structures, with a height of 150 feet, leans to such a degree that its top overhangs its base more than 12 feet; yet it has stood firm for centuries. In this case, the centre of gravity has been brought lower than it would otherwise have been, by the use of heavy materials at the bottom and lighter ones higher up. The lower stories are of dense volcanic rock, the middle stories of brick, and the upper ones of

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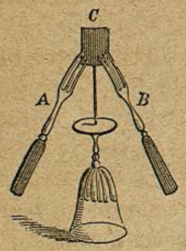
hardest to overturn? Why? Illustrate this point with Figs. 66 and 67. Give some familiar applications of this principle. 163. Why do those who pack goods in wagons place the heaviest lowest? In what has this principle been turned to account? Dean exceedingly porous stone. Thus built, the tower is much less liable to fall, than if the same material had been used throughout.

164. When the centre of gravity is brought beneath the point of support, the stability of a body is still further increased.

Fig. 69.



This is shown in Fig. 69. To balance a needle on its point is next to impossible, on account of the smallness of the base, and the height of the centre of gravity. It may be done, however, by running the head of the needle into a piece of cork, C, and sticking into opposite sides of this cork two forks, A, B, at equal angles. The whole may then be poised upon the needle's point on the bottom of a wine-glass. In this case, the heavy handles of the forks bring the centre of gravity below the point of support, in the stem of the glass.

Fig. 70.

ROCKING-HORSE.

The common toy known as the Rocking Horse, represented in Fig. 70, is made on this principle. To a horse of any light material, bearing a trooper or some other figure, is attached a wire to which a ball may be fastened. When the hind legs of the horse are placed on the stand without the ball, the line of direction falls outside of the base, and the horse and his rider fall. When the ball is attached, however, the centre of gravity is brought below the point of support; the horse will then maintain its upright position, and by moving the ball may be made to rock up and down.

165. Effect of Rotary Motion.—Rotary Motion, that is, motion round an axis, may keep a body from falling, even when its line of direction falls outside of its base. Thus, if a boy tries to balance his top on its point, he finds it impossible; but, when he spins it, it stands as long as the rotary motion continues. The centre of gravity is not over the point of support all the time the top is spinning, but is

scribe the tower of Pisa, and the materials of which it is built. 164. How is the stability of a body further increased? Show how a needle may be balanced on its point by applying this principle. Describe the Rocking Horse, and explain the principle involved. 165. What is meant by Rotary Motion? What is one of its effects? Why does a top fall over when we try to balance it on its point, but not fall when spinning?

constantly moving round the axis of motion; and, before the top can fall in consequence of its being on one side of the axis, it reaches the other side, and thus counteracts the previous impulse. Hence, the faster the top revolves, the steadier it is; as its motion slackens, it gradually reels more and more, and finally falls.

166. Centre of Gravity in Man.—The centre of gravity in the body of a man lies between the hips; the base is formed by lines connecting the extremities of the feet. A man enlarges this base, and therefore stands more firm, when he turns his toes out and places his feet a short distance apart. When old and infirm, he enlarges his base and increases his stability still further by using a cane.

When attempting to rise from a sitting position, a man must either bend his body forward or draw his feet backward, in order to bring his centre of gravity over his base; otherwise, he will fall back in making the attempt. So, a person who keeps his heels against a wall, can not stoop without falling, because he has no room to throw the middle of his body far enough back to keep the line of direction within the base.

Fig. 71.

Fig. 72.

Nature teaches a man when descending a height to lean backward, and when ascending to lean forward, as shown in Fig. 71. In like manner, when carrying a weight on one side, we sway our body to the other, like the man with the watering-pot, in Fig. 72. We find it easier to carry a pail of water in each hand than to carry but one, because the weights balance each other,

166. Where does the centre of gravity lie in a man's body? How may a man increase his stability? When attempting to rise from a sitting position, what must a man do? Why can not a person stoop, if he keeps his heels against a wall? What does nature teach a man to do, when descending a height? When ascending a height? When

and no effort is necessary to keep the line of direction within the base.

An infant that has not learned to balance itself in a standing position creeps on all fours without danger, because it thus brings its centre of gravity lower and enlarges its base. In order to walk, it must know how to preserve its balance; and, as some practice is necessary for this, the child in its first efforts is likely to fall. The same is the case with a dizzy or an intoxicated person, who for the time loses the power of preserving his balance—that is, of keeping his line of direction within his base.

167. When a person slips on one side, he naturally throws out his arm on the other. He thus seeks to bring back his centre of gravity over his base, and, when he can do so, he saves himself from falling. A person skating has to use his arms constantly for this purpose. Rope-dancers, in performing their feats, have to shift their centre of gravity from point to point with great rapidity; and, finding their arms insufficient for maintaining their balance on the rope, they use a long pole, with a slight motion of which they can throw the centre of gravity into any desired position.

Fig. 73.

SHEPHERDS OF LANDES.

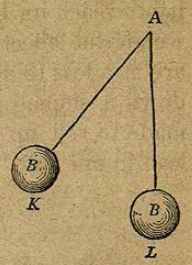
168. The shepherds of Landes [*lond*], in the south-west of France, have turned the art of balancing to good account. Having to tend their sheep in a region covered with marsh in winter and hot sand in summer, they mount on stilts about four feet high. Though the centre of gravity is raised, and their liability to fall thus increased, by practising from an early age they become exceedingly expert on these stilts, and can not only walk on them, but even dance, and run so fast that it is hard for a stranger to keep up with them.

169. Stable and Unstable Equilibrium.—The centre of gravity of every body tends to get to the lowest possible point.

carrying a weight on one side? Why do we find it easier to carry a pail of water in each hand than to carry but one? Why is an infant safer when creeping than when attempting to walk? Why does an intoxicated person reel? 167. When a person slips on one side, what does he do, and why? How do rope-dancers preserve their balance? 168. How have the shepherds of Landes turned the art of balancing to practical use? 169. What point does the centre of gravity tend to reach? Illustrate

A ball suspended by a string, as in Fig. 74, and released from the hand at K, or any other point, will not come to rest till it reaches L, because there its centre of gravity, B, is at its lowest point. Hence, when a pendulum or plummet comes to rest, it always hangs vertically.

Fig. 74.



A hammer, no matter in what way it is thrown up, descends with its iron part first, because the centre of gravity, which is in that part, tends to get as low as possible. For the same reason, a shuttlecock or an arrow, when it has reached its highest point, turns and descends with its heaviest part foremost.

170. A solid body resting on a surface in such a way that its centre of gravity is lower than it would be in any other position, is said to be in Stable Equilibrium. If its centre of gravity could be brought lower by placing it differently, it is said to be in Unstable Equilibrium.

Fig. 75.

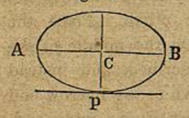
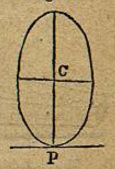


Fig. 76.



Thus, the oval body, A B, represented in Fig. 75, is in stable equilibrium, because its centre of gravity, C, is at its lowest possible point; and a force applied to either end will not cause it to fall over, but only to rock to and fro. In the position shown in Fig. 76, it is in unstable equilibrium, because its centre of gravity might be brought lower; and a slight push will overturn it and bring it to the position shown in Fig. 75. It is hardly possible to balance an egg on either end; but placed on its side, it rests securely.

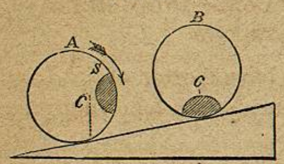
171. The stability of a sphere, or oval body like an egg, is increased by cutting it into two equal parts, as shown in Fig. 77. Bases of this shape are used in rocking toys, for supporting the figures of men and animals. Of this shape, also, are some of the huge Rocking Stones found in different parts of Europe, which are so nicely poised that the slightest push causes them to rock to and fro, while a dozen men can not overturn them.

Fig. 77.

this with Fig. 74. When a pendulum or plummet comes to rest, how does it hang? How does a hammer, a shuttlecock, or an arrow, descend, when thrown up into the air, and why? 170. When is a body said to be in Stable Equilibrium? When, in Unstable Equilibrium? Apply this in Figs. 75 and 76. 171. How may the stability of a

172. Paradoxes.—The tendency of the centre of gravity to reach its lowest possible point sometimes produces wonderful effects, or Paradoxes, for which the unlearned are at a loss to account. Thus, we know that a ball will roll down a sloping surface; but a ball of light wood may be made to roll up a sloping surface by inserting a piece of lead in one side.

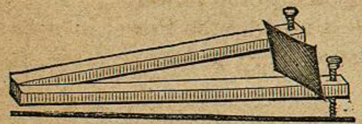
Fig. 78.



The ball A, for instance, loaded on one side with a plug of lead S, is placed on a sloping surface. The centre of gravity C, which is near S, at once tends to reach its lowest point; and owing to this tendency the ball rolls, till it reaches the position shown in B.

173. In like manner, a double cone, or body having the form of two sugar-loaves joined at their large ends, may be made to roll up an inclined plane. Fig. 79 represents two rails, joined at one end, but apart and somewhat elevated at the other. Place the double cone at the middle of the rails just described, and instead of rolling down to the narrow end it will roll up to the wide end. This is because the centre of gravity, though apparently going up, is really going down; for, as the rails diverge, they let the double cone further down between them.

Fig. 79.



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sphere or oval body be increased? For what are bases of this shape used? What stones are of this shape? 172. What are Paradoxes? How are they sometimes produced? How may a ball be made to roll up a sloping surface? Explain the principle involved, with Fig. 78. 173. Describe the experiment with the double cone, and explain the principle.

CHAPTER VII.

MECHANICS (CONTINUED).

THE MOTIVE POWER.—THE RESISTANCE.—THE MACHINE.—STRENGTH OF MATERIALS.

174. In a previous chapter we have treated of the Laws of Motion; we now proceed to consider the following practical points:—

I. The Motive Power, or Force by which motion is produced.

II. The Resistance to be overcome, or *work* to be done, which is always opposed to the Power.

III. The Machine, which is used by the Power in overcoming the Resistance, when it does not itself directly act.

IV. The Strength of the Materials employed.

In the case of a steamboat, steam is the Power by which motion is produced; the weight of the boat is the Resistance, which constantly opposes the Power. Since steam can not be directly applied in such a way as to move the boat, a Machine is used to aid in overcoming the Resistance; and this Machine is the engine. On the strength of the materials employed depend the usefulness and safety of the whole.

Motive Powers.

175. The chief powers used by man in producing motion are gravity, the elastic force of springs, his own strength, the strength of animals, wind, water, and steam.

176. *Gravity.—Springs.*—Gravity is applied by attaching weights to machinery, which they keep in motion by their constant downward tendency, as in certain kinds of

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174. What four subjects connected with Mechanics are treated of in the present chapter? In the case of a steamboat, what is the power? What, the resistance? What, the machine? On what does the usefulness of the whole depend? 175. Name the chief powers employed by man in producing motion. 176. How is gravity ap-