

gravity in the vertical line $h k$. Now suspend the body from another point z , and the centre of gravity will be on the line $z m$; then when the centre of gravity is on both the lines $p o$ and $z m$, it must evidently be at g , where the two lines cross one another (see Figs. 6 and 7).

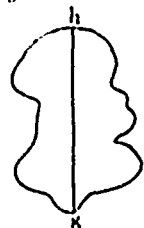


FIG. 6.

The lines $p o$ and $z m$, or the centre of gravity g , can also be found by balancing the body on a sharp edge. The centre of gravity of any figure or body is thus found by suspending or balancing the same in two different positions.

PROBLEM V.

In the foregoing (Figs. 3, 4 and 5), we have considered the levers to be inflexible lines without weight, which will answer when the centre of gravity of the material levers is in the fulcrum, like that of a weighing balance, or that of a wheel; but this centre of gravity is often located at a considerable distance from the fulcrum, as may be illustrated by Fig. 8, which is a lever of the first order, Fig. 3. The levers l and L are in the form of a beam resting on the fulcrum f and its centre of gravity at g . Let the weights of the

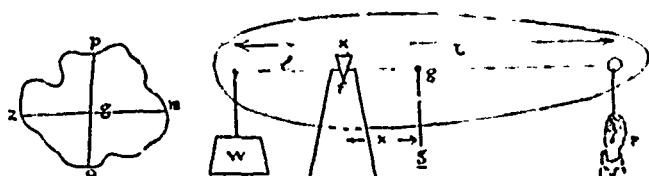


FIG. 8.

beam be represented by g , acting on the lever x ; there will be two static momentums $F L$ and $g x$ on one side of the fulcrum, against one $W l$ on the other side.

$$\begin{aligned} W l &= F L + g x \\ g x &= W l - F L \\ F &= \frac{W l - g x}{L} \\ l &= \frac{F L + g x}{W} \end{aligned} \quad \begin{aligned} F L &= W l - g x \\ W &= \frac{F L - g x}{l} \\ g x &= F L - F l \\ l &= \frac{F L - g x}{F} \end{aligned}$$

PROBLEM VI.

Fig. 9 is a lever of the third order, representing a safety valve as made and sold commercially.

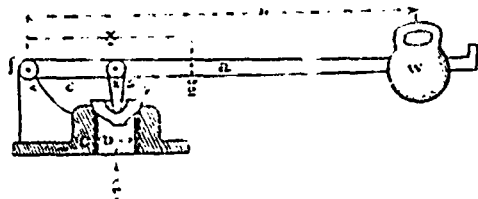


FIG. 9.

$$\begin{aligned} F l &= W l + g x \\ W l &= F l - g x \\ g x &= F l - W l \\ \frac{W l + g x}{l} &= F \\ \frac{F l - W l}{g} &= x \\ l &= \frac{F l - g x}{W} \end{aligned} \quad \begin{aligned} W &= \frac{F l - g x}{l} \\ \frac{F l - W l}{g} &= x \\ \frac{W l + g x}{F} &= l \end{aligned}$$

The formulas above are the same as those for the lever of the second order (Fig. 8).

The centre of gravity g may be found experimentally by balancing the beam over a sharp edge, when the distance x can be measured from the fulcrum f . It is here supposed that the levers l and L are in a straight and horizontal line. The form of the beam affects the location of the centre of gravity g , as shown in Fig. 7; but when this centre is known, the shape of the beam does not affect the static momentums. The pressure on the fulcrum f is equal to $W + g - F$.

Fig. 10 will better show the different functions of a safety valve when in service on a boiler under steam pressure.

A safety valve consists, primarily, of a movable disk, ring or plate, held from without, in the majority of cases, by a weight or a spring, over an orifice in a containing vessel against the pressure of a fluid within, so that it will resist any required pressure to which it may be adjusted, at the same time that any greater pressure will move it away from its seat and permit some of the contained fluid to escape. In the case of a steam safety valve, the contained fluid is steam in contact with water, the containing vessel is a steam boiler and the chambers and pipes in unobstructed communication therewith; and the office of the safety valve is to discharge all the steam which may at any time be generated within the boiler in excess of the steam drawn from it, after a certain pre-determined limit of pressure has been reached. Safety valves are generally circular or annular plates of brass or iron, with corresponding seats; and omitting as irrelevant many special forms, are of two classes:

First. Those which are held to their seats against internal pressure by

weights, either acting directly or through levers, in most general use with stationary boilers.

Second. Those which are held to their seats against internal pressure by springs, either acting directly or through levers, used almost exclusively upon locomotives, and to a great extent on portable steam engine boilers.

The form of safety valves in general use to-day, as before stated, were used by Papin in 1680, and are, therefore, two hundred years old, and probably much older.

If the contact between a safety valve and its seat were the contact of two sharp edges, like two circular knives edge to edge, the action of a valve in opening and closing would be simpler than it can generally be in practice. In fact, the surface in contact must have, for constructive reasons, a breadth very considerable in proportion to the diameter of the orifice closed by the valve; and since the areas of circles are to each other as the squares of their diameters, the area of the circle circumscribed by the outer border of the valve seat is materially larger than the area bounded by the inner border of the seat. The smaller area alone, within the seat, is acted on by the confined steam while the valve is closed; the larger area, within the outer border of the seat, is acted on by the escaping steam while the valve is open. It was, therefore, not unnatural to suppose that a safety valve, once opened against a resistance nearly constant, would immediately open still more widely, so as to give free outlet to the steam; and that it would remain open until a very sensible reduction of pressure in the boiler should enable a force, at first overcome by the higher pressure on the smaller area, to overcome in its turn the reduced pressure on the larger area.

That the reverse is true is well known. A safety valve, opened so as to permit the escape of a thin film of steam, can be further lifted so as to permit the free escape of steam, only by considerable increase of pressure, or by some special contrivance. It is usual to explain this phenomenon entirely by the increased resistance of springs due to increased tension, but this cannot be the sole cause, since the same thing is observed in a less degree where weights are used to close the valve. An additional cause is to be found in the expansion of a film of escaping steam between the valve and its seat, as in the familiar "pneumatic paradox" described by Bourne as "the tendency which escaping steam has to suck the valve down." There is also a little sluggishness and hesitancy about a movement produced by a very slight preponderance of nearly balanced forces. All motion is attended with some friction and some inertia; and decided preponderance is required to produce decided movement. To counteract this inertness, and to give promptness and decision—in a word, to give "pop!" to the action of a safety valve, both in opening and closing, many expedients have been invented, and will be described further on.

Reference being had to Fig. 10, the letters denote as follows:

1. D represents the diameter of the valve chamber C , also the smallest point of contact of the valve v .
2. W represents the weight acting on the long lever L .
3. x represents the weight of the lever arm a , valve v , and stem s , acting on the lever a .

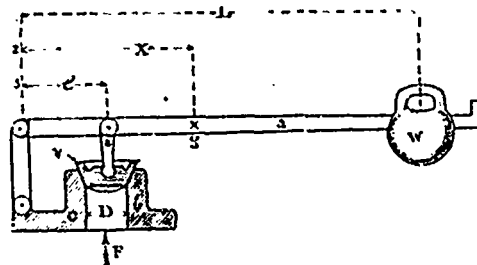


FIG. 10.

4. L represents the long lever, and is the distance from the centre of the weight W , to the fulcrum f , on which the lever arm a rests.
 5. l represents the short lever, and is the distance from the centre of the valve stem s to the fulcrum f .
 6. x represents the distance from the centre of gravity g , to fulcrum f .
 7. f represents the fulcrum, and is the support on which the lever arm a rests.
 8. a represents the lever arm, on which is placed the weight W , and to which is attached the valve stem s .
 9. v represents the valve covering the chamber C .
 10. s represents the valve stem, or guide, of valve v .
 11. g represents the centre of gravity of the lever arm a , valve v , and stem s .
 12. p represents the steam pressure above that of atmosphere (as shown by the steam gauge).
 13. A represents the area of the valve chamber C , and is the square of the diameter D , multiplied by the decimal 0.7854; or $0.7854 \times D^2$.
 14. F represents the force p due to the weight W , multiplied by the long arm L added to the momentum $W x$, this latter being obtained simply by multiplying the weight W by the distance x , which is a constant quantity in the graduation of the lever for different pressures of steam.
- From the above illustration it will be seen that there are three forces.
- First. The weight W acting on the long lever L .
- Second. The weight of the lever arm a , valve v , and stem or guide s , acting on lever x .
- Third. The force due to the steam pressure p , per square inch, multiplied by the area A , of the valve v , in square inches, acting on the short lever l .

(To be Continued.)