GRAPHICS

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BY

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PREFACE.

These notes contain the substance of lectures on the subject of graphics which have been given to the students in Mechanical, Electrical and Chemical Engineering at the University of Pennsylvania for a number of years past.

They are intended to cover only fundamental principles, and those familiar with the subject will recognize that the methods of treatment used by many writers have been utilized in their preparation. Many of the short cuts in common use are not referred to in the text, as the time allotted to this work is limited, and while such short cuts are of special value in special work, they are readily grasped by one who has a good fundamental knowledge of the entire subject.

The treatment of trusses is short, but is believed to be full enough to enable beginners to grasp the general principles. The graphics of machines is limited to such examples as will most clearly set forth the effect of friction on the line of action of the forces to be determined. The latter portion of the book is devoted to forces not in the same plane, such as occur in many pieces of machinery.

It is intended that the book shall be used as a reference book, many numerical problems being worked out on the drawing board.

The writer is indebted to practically every author on the subject for methods or suggestions, and has simply made a continuous story of the subject matter.

University of Pennsylvania,
June 1, 1908.

GRAPHICS.

Equilibrium. A body is said to be in equilibrium when it is in the condition that is ordinarily understood by the expression "at rest," or when the body is moving with a uniform velocity.

A body cannot be in equilibrium under the action of a single force.

When two forces act on a body in equilibrium, the forces must be equal in amount, opposite in direction, and act in the same line. If the two forces are not equal in amount, they can be replaced by a single force, which will have the same effect on the body. If they are not opposite in direction, they will have a resultant single force. If they do not act in the same line, they can be replaced by a single force, or by a turning couple, or by both, and the body is not in equilibrium.

When a body is in equilibrium under the action of three forces, these forces must lie in the same plane, they must pass through the same point, and the force polygon must close.

Force Polygon. To draw a force polygon, suppose, in Fig. 1, a series of forces represented by **A, B, C** and **D** act at the point **O,** in the direction shown, the magnitude of the forces being as shown on the figure, 5, 4, 3 and 6 pounds. Begin at any point, *a*, and draw a line parallel to **OA** to the point *b*, making the distance *ab* equal to 5 pounds, to any scale, the line being drawn from *a* in the direction in which the force **AO** acts, as shown by the arrow head.

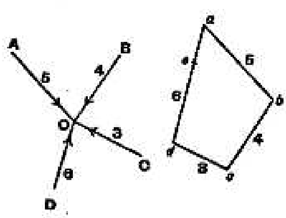

Fig. 1.—Force Polygon.

From *b*, draw a line *bc* parallel to **BO**, and in length equal to 4 pounds to the same scale. Through *c* draw a line parallel to **CO**, and in length equal to 3 pounds to scale; and from *d* draw a line parallel to **DO**, and in length equal to 6 pounds to the same scale. This brings us again to the point *a*. This diagram, *abcd*, is the force polygon, and, in this case, the force polygon closes.

Resultant Force. If, however, the force **D**, instead of reaching to the point *a*, extended only to the point *e*, the force polygon would not close, and the force *ea* would be required to close the polygon, or the force *ea* is the force necessary to hold the other forces in equilibrium, and the force *ae*, acting in the opposite direction to *ea*, is the resultant of the forces **A**, **B**, **C** and **D**.

Any Number of Forces. When any number of forces hold a body in equilibrium, the force polygon must close, and, in addition, the moment of all the forces about any point must be zero.

The statements already made about two and three forces are simply special cases of the above statements.

When any number of forces act on a body, the components of these forces acting along each of three lines at right angles to each other, such as the three converging edges of a box, must form closed force polygons if the body is in equilibrium, and, in addition, the moment of each set of components, taken about any point, must be zero.

Three Forces. Most of the problems in graphics relate to a condition of affairs in which three forces act at a point.

Referring to Fig. 2, if three forces, **AB**, **BC** and **CA**, act at the same point, one force only being known, and if these three forces are in equilibrium, a force triangle can be drawn. First lay off *ca* from *c* upwards, proportional in length to the value of the force **CA**. Through *c* draw a line parallel to **CB**, and through *a* draw a line parallel to **AB**, and call the intersection of these two lines *b*. The force triangle for the forces acting at the point **ABC** is the triangle *abc*, and the amounts of the unknown forces are given by the sides of the triangle *bc* and *ab*.

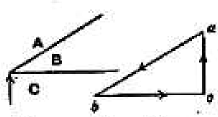

Fig. 2.—Three Forces.

Triangular Frame. Most of the structures treated of are built up of a series of triangles having forces acting at the vertices of each triangle. This form is used because external forces will not cause the structure to collapse and because the internal force in each member can be accurately determined. It is assumed that the parts are held together by pins, and are not riveted together. Fig. 3 shows such a triangular frame. Assume that the external loads, acting on this frame, are as shown at **AB, BC, CD, DE** and **EA.** As the forces acting at each vertex of this diagram are in equilibrium, it should be possible to draw a triangle of forces, or a closed polygon of forces at each point. In Fig. 4, the triangle *afe* determines the value of the forces acting at the left-hand corner, as the external forces are assumed to be known. At the point **ABGF**, the value of the forces **AB** and *fa* are known, **AB** being given, and the value of the force *fa* having been determined from Fig. 4. Lay off the known forces in the direction in which they act, *faab*, and *fb* is the resultant of the known forces acting at this point. As these forces, together with **BG, GF,** hold the point **ABGF** in equilibrium, draw through *b* a line parallel to **BG,** and through *f* a line parallel to **FG,** and call their intersection *g*. The force acting in **FG** is *fg* and the force acting in **BG** is *bg*.

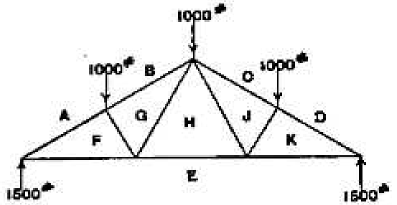

Fig. 3.—Triangular Frame.

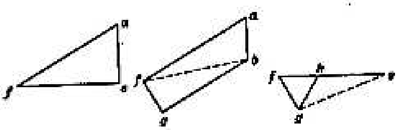

Fig. 4.—Separate Polygons.

Passing now to the vertex **GHEF,** the known forces are those acting in **EF** and in **FG.** Laying these forces down in the order in which they act, *eg* is the resultant of the known forces acting at this point. If through *e* a line is drawn parallel to **EH,** and through *g* a line parallel to **GH,** and the intersection of these lines is called *h*, then *eh* is the force acting in **EH** and *gh* is the force acting in **GH.** Similar diagrams could be drawn for the vertexes, **BCJHG, CDKJ, JKEH,** and the right-hand corner.