CHAPTER 5

Statics of one object

One object is in equilibrium if the forces and moments balance. For a particle, force balance tells all. But for an extended object, moment balance is also essential. There are special shortcuts for an object that has exactly two or exactly three forces acting on it. If friction forces are relevant the possibility of motion needs to be taken into account. Many real-world problems are not statically determinate and thus yield either only partial solutions, or yield full solutions after you have made extra assumptions.

The goal here is to find unknown aspects of the forces acting on one object. The object is typically a part of a machine or structure. Such a part is also called a 'body'. By 'unknown' we mean 'unknown at the outset' or 'you-need-to-do-mechanics-calculations-to-find'. Most often 'unknowns' are tensions in ropes or rods, contact forces where one part presses and rubs against another, and the force on an object at a point of connection to another object. We will also find 'unknown' forces and moments that one part of an object applies to another part of the same object. Finally we might also find the 'unknown' direction or point of application of a force that has an *a priori* known magnitude.

Needed skills

Throughout this and all later chapters you need mastery of the vector and free-body diagram skills and concepts from chapters 2 and 3.

Statics is a subset of dynamics

Statics is the mechanics of things that don't move. But everything does move, at least a little. So, strictly speaking, dynamics is always the applicable subject. For many practical problems, however, statics is a good approximation of dynamics, very good. With little loss of accuracy, sometimes very little loss, and a great saving of effort, usually a very great saving, statics can be used instead of dynamics. Statics is a useful model. Even for a fast-moving system, say an accelerating car, statics calculations are appropriate for many of the parts. Although statics is a subset of dynamics (See box 5.2 on page 249) typical engineers do more statics calculations than dynamics calculations. Statics is the core of structural and strength analysis. Statics is the central tool used to predict when a structure or part will or will not break. Finally, Statics is good preparation for Dynamics ①.

① Ironically, for some people the main benefit from learning dynamics is the side effect of better mastery of the generally-more-useful statics.

For all of statics, we neglect the role of inertia. We assume forces and moments balance each other. We assume static equilibrium.

Two-dimensional and three-dimensional mechanics

The world we live in is three-dimensional and the theory of mechanics is a three-dimensional theory. But three dimensions are harder to understand than two. So most learning and much engineering analysis is done in two dimensions. You can't critically judge the degree of simplification this involves until you understand 3D mechanics. But you aren't ready to learn 3D mechanics until you understand 2D mechanics. We escape this catch-22 by being casual about the precise meaning of the 2D world view. For now we think of cylinders and spheres as circles, of boxes as rectangles, and of cars as things with two wheels (one in front, one in back).

Static equilibrium in a nutshell

The basic idea for all of statics is this: if the forces on a system (i.e., the forces showing on a free-body diagram of the system) satisfy eqs. (Ic) and (IIc) (inside cover) the system is said to be in *static equilibrium* or just *in equilibrium*②.

② To be precise, static equilibrium requires that the system and all subsystems, all billion gazillion of them (all the different ways you could cut a piece out of your system), satisfy the equilibrium conditions. However, for simplicity at this point in the book, we don't concern ourselves much with subsystems, just with a single whole object.

> A system is in static equilibrium if the applied forces and moments add to zero.

Another way to say this is that

A system in static equilibrium satisfies the linear and angular momentum balance neglecting the inertial ($m\vec{a}$) terms.

A final alternative description of statics is:

The full collection of forces on a system in static equilibrium are equivalent to (see Section 2.1 on page 139) a zero force and a zero couple.

The statics story is now, in-principle, complete. You have the tools (vectors and free-body diagrams) and you know the basic facts (the definition of statics, above). These are enough. But we'll guide you through some of the subtleties, warn you away from common misconceptions, and teach you some of the tricks of the trade. You will see that the simply-stated laws of statics (above) allow you to accurately calculate useful things, things that most people who have not studied statics only vaguely understand.