

8.4 Free-body Force Diagram

8.4.1 System

When we try to describe forces acting on a collection of objects we must first take care to specifically define the collection of objects that we are interested in, which define our *system*. Often the system is a single isolated object but it can consist of multiple objects.

Because force is a vector, the force acting on the system is a vector sum of the individual forces acting on the system

$$\vec{\mathbf{F}} = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 + \cdots \quad (8.4.1)$$

A *free-body force diagram* is a representation of the sum of all the forces that act on a single system. We denote the system by a large circular dot, a “point”. (Later on in the course we shall see that the “point” represents the center of mass of the system.) We represent each force that acts on the system by an arrow (indicating the direction of that force). We draw the arrow at the “point” representing the system. For example, the forces that regularly appear in free-body diagram are contact forces, tension, gravitation, friction, pressure forces, spring forces, electric and magnetic forces, which we shall introduce below. Sometimes we will draw the arrow representing the actual point in the system where the force is acting. When we do that, we will not represent the system by a “point” in the free-body diagram.

Suppose we choose a Cartesian coordinate system, then we can resolve the force into its component vectors

$$\vec{\mathbf{F}} = F_x \hat{\mathbf{i}} + F_y \hat{\mathbf{j}} + F_z \hat{\mathbf{k}} \quad (8.4.2)$$

Each one of the component vectors is itself a vector sum of the individual component vectors from each contributing force. We can use the free-body force diagram to make these vector decompositions of the individual forces. For example, the x -component of the force is

$$F_x = F_{1,x} + F_{2,x} + \cdots \quad (8.4.3)$$

8.4.5 Modeling

One of the most central and yet most difficult tasks in analyzing a physical interaction is developing a physical model. A physical model for the interaction consists of a description of the forces acting on all the objects. The difficulty arises in deciding which forces to include. For example in describing almost all planetary motions, the Universal Law of Gravitation was the only force law that was needed. There were anomalies, for example the small shift in Mercury’s orbit. These anomalies are interesting because they may lead to new physics. Einstein corrected Newton’s Law of Gravitation by introducing General Relativity and one of the first successful predictions of the new theory was the perihelion precession of Mercury’s orbit. On the other hand, the anomalies may simply

be due to the complications introduced by forces that are well understood but complicated to model. When objects are in motion there is always some type of friction present. Air friction is often neglected because the mathematical models for air resistance are fairly complicated even though the force of air resistance substantially changes the motion. Static or kinetic friction between surfaces is sometimes ignored but not always. The mathematical description of the friction between surfaces has a simple expression so it can be included without making the description mathematically intractable. A good way to start thinking about the problem is to make a simple model, excluding complications that are small order effects. Then we can check the predictions of the model. Once we are satisfied that we are on the right track, we can include more complicated effects.

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