

13.1 Newton's Law of Universal Gravitation

This section replaces the second-to-last paragraph on page 375.

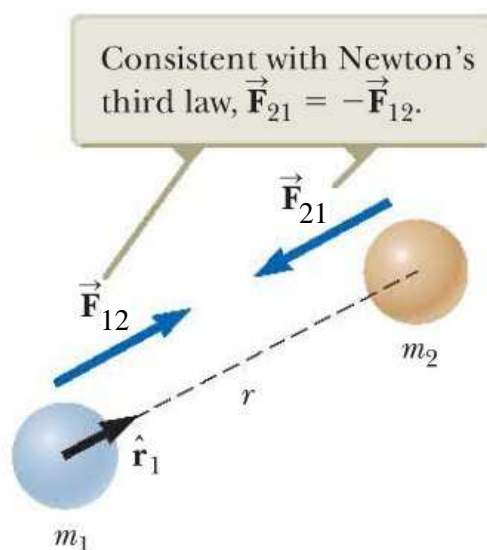
The form of the force law given by Equation 13.1 is often referred to as an **inverse-square law** because the magnitude of the force varies as the inverse square of the separation of the particles. ¹ We shall see other examples of this type of force law in subsequent chapters. We can express this force in vector form by defining a radial unit vector $\hat{\mathbf{r}}_1$ to be applied when the origin is chosen to be at the location of particle 1 (Fig. 13.2). Because this unit vector is directed from particle 1 towards particle 2, the force exerted on particle 2 by particle 1 is

$$\vec{\mathbf{F}}_{21} = -G \frac{m_1 m_2}{r^2} \hat{\mathbf{r}}_1 \quad (13.3)$$

where the negative sign indicates that particle 2 is attracted to particle 1; hence, the force on particle 2 must be directed toward particle 1 (inwardly radial, as opposed to outwardly radial). By Newton's third law, the force exerted on particle 1 by particle 2, designated $\vec{\mathbf{F}}_{12}$, is equal in magnitude to $\vec{\mathbf{F}}_{21}$ and in the opposite direction. That is, these forces form a third-law pair, and $\vec{\mathbf{F}}_{12} = -\vec{\mathbf{F}}_{21}$.

Two features of Equation 13.3 deserve mention. First the gravitational force is a field force that always exists between two particles, regardless of the medium that separates them. Because the force varies as the inverse square of the distance between the particles, it decreases rapidly with increasing separation.

Figure 13.2 The gravitational force between two particles is attractive. The unit vector $\hat{\mathbf{r}}_1$ is directed from particle 1 toward particle 2.



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¹ An *inverse* proportionality between two quantities x and y is one in which $y = C/x$, where C is a constant. A *direct* proportionality between x and y exists when $y = Cx$.