

Chapter Summary

Chapter Summary: Newton's Laws of Motion

Forces

A system is an object or collection of objects we choose to analyze. Anything outside the system is called the environment.

A force is vector quantity, and so has magnitude and direction. A force acts on an object and is always caused by another object. External forces are forces by objects in the environment on a chosen system. The net force on a system is the sum of all external forces acting on the system, as given by [Equation 5.1](#).

$$\vec{F}_{\text{net}} = \sum \vec{F}$$

Constructing Free-Body Diagrams

1. Draw the system or object under consideration; it does not have to be artistic. At first, you may want to draw a circle around the system of interest to be sure you focus on labeling the forces acting on the system.
2. Draw all forces that act on the system, representing these forces as vectors. Remember that forces on a system are caused by objects in the environment, so consider all objects that are in contact with the system or that are exerting long-range forces on the system. Do not include the net force on the object. Do not include forces that the system exerts on objects in the environment. The forces drawn directly on the picture of the system is sometimes called an "extended body diagram."
3. To focus more clearly on the forces, draw a separate diagram that represents the system as a dot (this dot models the system as a particle). Redraw all forces acting on the system with the vector tails at the dot. This is called the "free-body diagram."

4. It is often useful to draw an xy -coordinate system along with the free-body diagram. The particle is often at the origin of the coordinate system. You are free to choose the axes to be in any direction you like. Often it is useful to choose axes that make the calculations easier.
5. If necessary, convert the free-body diagram into a more detailed diagram showing the x - and y -components of the forces. Be careful not to "double count" a force and its components. To avoid this double counting, you may want to draw the components in a different color, or erase the original forces and replace them with their x - and y -components, or even draw a second free-body diagram consisting of only the components.
6. If there are two systems in the problem, draw a separate free-body diagram for each system.

Newton's First Law of Motion

Newton's first law states that every object maintains a constant velocity except to the extent it is acted upon by a net external force.

An inertial reference frame is one where Newton's first law holds true. A reference frame that is at rest to the fixed stars is inertial, as is any frame moving at a constant velocity with respect to this frame.

Newton's Second Law of Motion

Newton's second law states the acceleration of an object is equal to the net force acting on the object divided by its mass ([Equation 5.2](#)).

$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$$

The equations for the individual components are ([Equation 5.3](#)):

$$a_x = \frac{F_{\text{net},x}}{m}, \quad a_y = \frac{F_{\text{net},y}}{m}, \quad a_z = \frac{F_{\text{net},z}}{m}$$

Newton's second law can also be written as [Equation 5.5](#):

$$\vec{F}_{\text{net}} = m\vec{a}$$

Newton's Third Law of Motion

Newton's third law states that the force that object A exerts on object B is equal in magnitude and opposite in direction to the force that object B exerts on object A. Mathematically, this is given by [Example 5.9](#).

$$\vec{F}_{\text{A on B}} = -\vec{F}_{\text{B on A}}$$

Weight

Weight is the gravitational force acting on an object. Weight is equal to the mass of the object times the gravitational field at its location. The magnitude of weight is given by [Equation 5.6](#).

$$F_g = mg$$

On the surface of the Earth, the gravitational field has a magnitude of $g = 9.8 \text{ m/s}^2$,

Spring force

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