Applying Newton's Laws of Motion

Topic 2b

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Learning Outcomes for Topic 2b

- How to use Newton's ***first law*** to solve problems involving forces that act on a body in equilibrium.
- How to use Newton's ***second law*** to solve problems involving the forces that act on an accelerating body.

Overview of topic 2b

- Using Newton’s first law
- Problem solving strategy
- Apparent weight & weightlessness
- Frictional forces
- Kinetic and static friction

Introduction

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- Newton's three laws of motion can be stated very simply
  - applying these laws to real-life situations requires *analytical skills and problem-solving techniques*.
- In this chapter we'll begin with **equilibrium problems**
  - we analyze the forces that act on a body that is at rest or moving with constant velocity.
- We'll then consider bodies that are **not in equilibrium**, for which we'll have to deal with the **relationship between forces and motion**.

Using Newton's first law

- A body is in ***equilibrium*** when it is at rest or moving with constant velocity in an inertial frame of reference, and the **net force acting on a body is 0**
- The essential physical principle here is ***Newton's first law***

Newton's first law: *Net* force on a body ...

$$\sum \vec{F} = 0$$

... must be *zero* for a **body in equilibrium.**

Sum of x-components of force on body must be zero.

$$\sum F_x = 0$$

Sum of y-components of force on body must be zero.

$$\sum F_y = 0$$

Problem-solving strategy (1st Law)

- ***Identify*** the relevant concept: You must use Newton's first law.
- ***Set up*** the problem by using the following steps:

1. Draw a sketch of the physical situation.
2. Draw a ***free-body diagram*** for each body that is in equilibrium.
3. Ask yourself what is interacting with the body by contact or in any other way.
   - If the mass is given, use ***w = mg*** to find the weight.
4. Check that you have only included forces that act **on the body.**
5. Choose a set of coordinate axes and include them in your free-body diagram.

Problem-solving strategy (1st Law)

- ***Execute*** the solution as follows:
  1. Find the components of each force along each of the body's coordinate axes.
  2. Set the sum of all *x*-components and *y*- components of force equal to zero in separate equations.
  3. If there are two or more bodies, repeat all of the above steps for each body.
  4. If the bodies interact with each other, use ***Newton's third law*** to relate the forces they exert on each other.
  5. Ensure that you have as many independent equations as the number of unknown quantities. Then solve to obtain the target variables.
- ***Evaluate*** your answer.

Problem-solving strategy (2nd Law)

- In ***dynamics*** problems, we apply Newton's second law to bodies on which the net force is ***not zero***.
- These bodies are **not in equilibrium** and hence are accelerating:

Newton's second law: If *net* force on a body is not zero ...

$$\sum \vec{F} = m\vec{a}$$

... body has *acceleration* in same direction as net force.

Mass of body

Each component of net force on body ...

$$\sum F_x = ma_x \qquad \sum F_y = ma_y$$

... equals body's mass times corresponding acceleration component.

Problem-solving strategy (2nd Law)

- ***Identify*** the relevant concept: You must use Newton's second law.
- ***Set up*** the problem by using the following steps:
  1. Draw a simple sketch of the situation that shows each moving body. For each body, draw a free-body diagram that shows all the forces acting *on* the body.
  2. Label each force. Usually, one of the forces will be the body's ***weight w = mg***.
  3. Choose your *x*- and *y*-coordinate axes for each body, and show them in your free-body diagram.
  4. Identify any other equations you might need.
  5. If more than one body is involved, identify if there are any relationships among their motions
     - for example, they may be connected by a rope.

Problem-solving strategy (2nd Law)

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- ***Execute*** the solution as follows:
  1. For each body, determine the components of the forces along each of the body's coordinate axes.
  2. List all of the known and unknown quantities. In your list, identify the target variable or variables.
  3. For each body, write a separate equation for each component of ***Newton's second law***. Write any additional equations that you identify (you need as many equations as there are target variables).
  4. Do the easy part—the math! Solve the equations to find the target variable(s).
- ***Evaluate*** your answer.

End