System and Free Body Diagrams

A Systematic Approach to Force Diagrams

http://newsletter.oapt.ca/files/Systems-and-FB-Diagrams.html

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Opening Quote

“When asked to draw a force diagram for some simple situation, most students emerging from any level of introductory physics course are likely to draw objects which look like a porcupine shot by an Indian hunting party—the number and direction of pointed entities being essentially stochastic.”

– Arnold Arons (1979)

CH4/Porcupinebros.jpg

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How to Draw System Diagrams

1. **Draw a simple sketch**
    - Keep it simple
    - Use stick figures when possible
    - Include important elements (ground, ropes, springs)
2. **Draw a closed curve**
    - Enclose object of interest
    - Curve should hug object closely
    - Label inside as "system", outside as "environment"

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System Diagrams (continued)

3. **Label contact forces**
   - Identify forces at system-environment boundary
   - Name both objects involved
   - Multiple forces may exist at one point
4. **Label non-contact forces**
   - Include gravity
   - Include electromagnetic forces
   - Write these as an aside

System Diagrams (continued)

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How to Draw Free Body Diagrams

1. **Draw a dot**
    - Represents "the system"
    - Makes all diagrams uniform
    - Easier to grade and understand
2. **Draw force arrows**
    - Start from the central dot
    - Draw to scale when possible
    - Include only forces from system diagram
    - Label each force clearly

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Why Do We Need These Diagrams?

Key Benefits:

1. They help us organize our thoughts about forces
2. They prevent us from forgetting forces
3. They make solving problems easier

Remember:

- Always choose your system first
- Label ALL forces clearly
- Show contact and non-contact forces

Tips for Success

Your Diagram Checklist:

1. Start with a simple sketch
   - Keep it neat
   - Include only what matters
2. Label everything clearly
   - All forces named
   - Direction shown
3. Check your work
   - Did you include gravity?
   - Are contact points marked?

Example Application

Tow Truck Scenario:

- System: Car being towed

CH4/towtruck.png

CH4/towtruck.png

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Newton's Third Law - Statement

- **Key Principle:** For every action force, there is an equal and opposite reaction force
- When a first body exerts a force on a second body:
  - The second body exerts an equal force back
  - The forces are equal in magnitude
  - The forces act in opposite directions

Example: Physics Teacher with Cart

Problem Setup

- Teacher mass: 65.0 kg
- Cart mass: 12.0 kg
- Equipment mass: 7.0 kg
- Applied force: 150 N backward
- Friction force: 24.0 N

CH4/Picture.png

Solution Strategy

- Define the system:
  - Teacher + Cart + Equipment
- External forces:
  - Floor's forward force: 150 N
  - Friction force: -24.0 N
- Net force calculation:

$$\mathbf{F}_{\text{net}} = \mathbf{F}_{\text{floor}} - f = 150\text{ N} - 24.0\text{ N} = 126\text{ N}$$

CH4/Picture.png

Common Mistakes to Avoid

Important Notes

- Don't include internal forces in net force calculations
- Internal forces cancel out within the system
- Examples of internal forces:
  - Force between teacher's hands and cart
  - Force between cart and equipment
- System definition is crucial for problem-solving

Tips for Success

Key Points

- Always identify the system clearly
- Draw a free-body diagram
- Label all external forces
- Remember:
  - Action and reaction forces act on different objects
  - Forces between system components cancel out
  - Net force considers only external forces

Practice Problem

An astronaut in space wants to move upward. Which direction should they throw an object?

- **Correct Answer:** Downward
- **Explanation:**
    - Action: Astronaut throws object downward
    - Reaction: Object pushes astronaut upward
    - Forces are equal in magnitude, opposite in direction

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