

System and Free Body Diagrams

A Systematic Approach to Force Diagrams

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

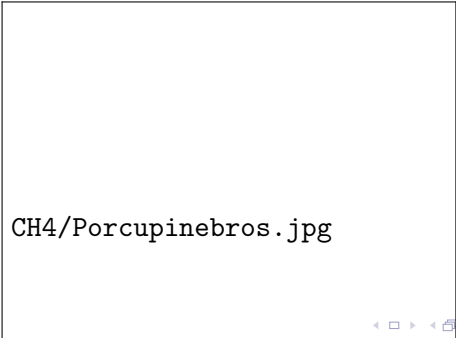
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Opening Quote

“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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3 Why System & Free Body Diagrams Matter

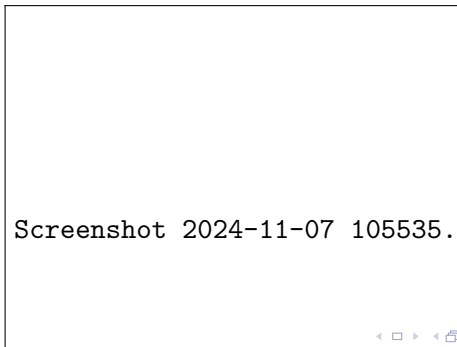
How to Draw System Diagrams

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

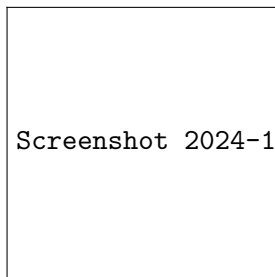
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How to Draw Free Body Diagrams

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

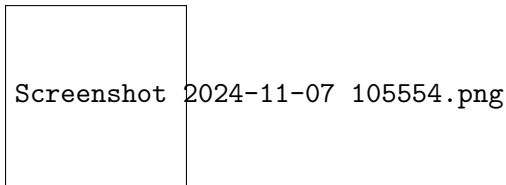


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Why Do We Need These Diagrams?

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

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

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

Acknowledgments

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- Reference: Knight, R.D., "FIVE EASY LESSONS: Strategies for Successful Physics Teaching"