

# System and Free Body Diagrams

## A Systematic Approach to Force Diagrams

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

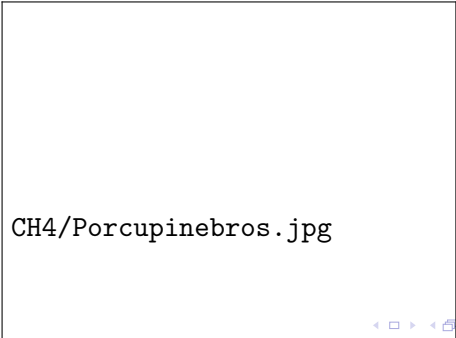
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# Opening Quote

*“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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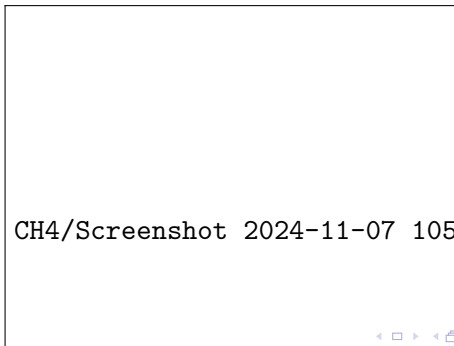
# How to Draw System Diagrams

## 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

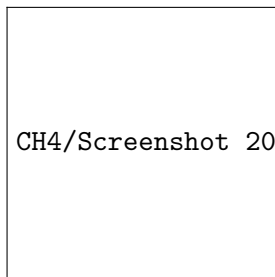
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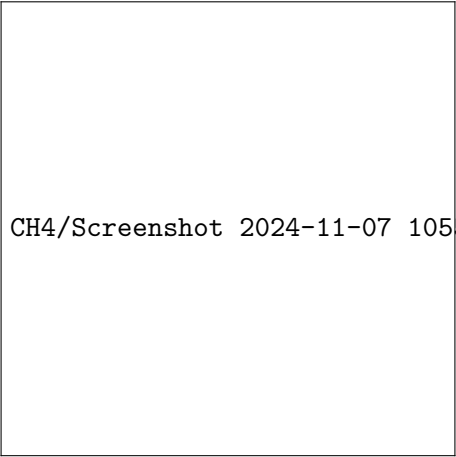
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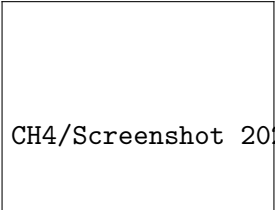
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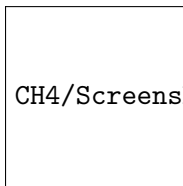
# How to Draw Free Body Diagrams

## 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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