Module 2 · Week 1 · Lesson

Forces and Interactions

PH11-9

ORIENTATION

Lesson goal: build accurate physics fluency for forces and interactions and use that fluency to support clear HSC-style scientific writing.

This page is materialised into the MentorMind course shell from existing teaching, textbook, and eduKG material. Use it as the main lesson surface; use the tutor for targeted repair, worked examples, and concise writing feedback.

SYLLABUS INQUIRY QUESTION

- How do interactions between objects produce changes in motion?

From The Feynman Lectures on Physics, Vol I, Chapter 9:

A force is not a property of a single object. It is a description of an interaction between two objects, and it always has a direction.

LEARNING OBJECTIVES

- Identify contact and field forces.
- Draw and interpret free-body diagrams.
- Calculate weight and normal force in simple cases.
- Determine net force and equilibrium conditions.

CONTENT

Types of forces

Forces arise from interactions between objects. We classify them into two categories:

Contact forces require physical touching:

- **Normal force (N)**: Perpendicular push from a surface
- **Friction (f)**: Parallel to surface, opposes relative motion
- **Tension (T)**: Pull through a rope, string, or cable
- **Applied force (F)**: Push or pull from an external agent

Field forces act at a distance:

- **Gravitational force (Weight, W)**: Attraction toward Earth's centre
- **Electric force**: Between charged objects
- **Magnetic force**: Between magnets or moving charges

The SI unit of force is the **newton (N)**, where 1 N = 1 kg·m/s^2.

Interactive: Force Categories

Explore different types of forces acting on objects:

Interpreting the diagram:

- Red vector (W): Weight pulling downward
- Blue vector (N): Normal force pushing upward from surface
- Green vector (F): Applied force pushing right
- Purple vector (f): Friction opposing the motion

Weight and normal force

Weight is the gravitational force on a mass:

$$W = mg$$

where $g = 9.8$ m/s^2 near Earth's surface.

Normal force is the surface's response to being compressed. On a horizontal surface at rest, the normal force balances weight:

$$N = W = mg$$

- **Mass (m)** is the amount of matter, measured in kilograms (kg)
- **Weight (W)** is a force, measured in newtons (N)

An astronaut's mass is the same on Earth and the Moon, but their weight differs because g differs.

Free-body diagrams

A **free-body diagram** (FBD) shows only the forces acting on a single object. Rules for drawing:

1. Represent the object as a dot or simple shape
2. Draw all forces as arrows starting from the object
3. Label each force with its name and magnitude
4. Include only forces acting **on** the object, not forces it exerts

Interactive: Building a Free-Body Diagram

Consider a box being pushed across a floor. The free-body diagram shows all forces on the box:

The **net force** is the vector sum of all forces. In this example:

- Vertical: $N - W = 0$ (equilibrium vertically)
- Horizontal: $F - f = 25 - 10 = 15$ N to the right

Equilibrium

When the net force is zero, the object is in **equilibrium**:

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

An object in equilibrium is either:

- **Static equilibrium**: At rest
- **Dynamic equilibrium**: Moving with constant velocity

An object in equilibrium will remain at rest or continue moving at constant velocity. This is Newton's First Law, covered in the next section.

Interactive: Equilibrium vs Acceleration

Compare the net force when forces are balanced versus unbalanced:

WORKED EXAMPLES

Example 1: Weight and normal force

A 6.0 kg box rests on a horizontal floor. Find the weight and normal force.

Solution:

1. Weight: $W = mg = 6.0 \times 9.8 = 58.8$ N downward
2. At rest on a level surface, the net vertical force is zero
3. Therefore: $N = W = 58.8$ N upward

Example 2: Net force in one dimension

Two horizontal forces act on a trolley: 14 N east and 9 N west.

Solution:

1. Choose east as positive
2. Net force: $F_{net} = 14 - 9 = 5$ N east
3. The trolley accelerates east (in the direction of net force)

Example 3: Tension in a hanging mass

A 2.5 kg mass hangs at rest from a light rope. Find the tension.

Solution:

1. Net force is zero (equilibrium)
2. Forces: Weight down, Tension up
3. $T = W = mg = 2.5 \times 9.8 = 24.5$ N upward

COMMON MISCONCEPTIONS

- **Misconception:** Weight and mass are the same. **Correction:** Mass is measured in kg, weight in N. Weight depends on location; mass does not.
- **Misconception:** The normal force always equals weight. **Correction:** This is only true on horizontal surfaces with no other vertical forces. On slopes or with additional forces, $N \neq W$.
- **Misconception:** Opposing forces always cancel. **Correction:** Forces only cancel if they act on the **same object** with equal magnitudes and opposite directions.

- **Misconception:** A free-body diagram should show all forces in the problem. **Correction:** Show only forces acting **on** the chosen object, not forces it exerts on others.

PRACTICE QUESTIONS

Easy (2 marks)

A 4.0 kg object rests on a table. Calculate its weight.

- Use $W = mg$ (1)
- Correct value: $W = 4.0 \times 9.8 = 39.2$ N with units (1)

Answer: 39.2 N (or 39 N)

Medium (4 marks)

A box is pulled with 30 N east while friction acts 12 N west. Determine the net force and describe the motion.

- Correct net force calculation: $F_{net} = 30 - 12 = 18$ N (2)
- Direction of net force: east (1)
- Statement that box accelerates east (1)

Answer: Net force is 18 N east. The box accelerates to the east.

Hard (5 marks)

A 10 kg crate is pulled upward by a cable with 140 N tension. Determine the net force and state whether the crate accelerates or is in equilibrium.

- Weight calculation: $W = 10 \times 9.8 = 98$ N (1)
- Net force calculation: $F_{net} = 140 - 98 = 42$ N upward (2)
- Correct statement: crate accelerates upward (1)
- Optional: Calculate acceleration $a = 42/10 = 4.2$ m/s^2 (1)

Answer:

- Weight = 98 N down
- Net force = 140 - 98 = 42 N upward
- The crate accelerates upward at 4.2 m/s^2

MULTIPLE CHOICE QUESTIONS

Test your understanding with these interactive questions:

SUMMARY

- Forces describe interactions between objects and always have direction
- Contact forces (normal, friction, tension) require physical contact
- Field forces (gravity, electric, magnetic) act at a distance
- Weight is $W = mg$ where $g = 9.8$ m/s^2
- Free-body diagrams show all forces acting on one object only
- Equilibrium means $\vec{F}_{net} = 0$ (at rest or constant velocity)

SELF-ASSESSMENT

Check your understanding:

After studying this section, you should be able to:

- [ ] Distinguish between contact and field forces
- [ ] Calculate weight using $W = mg$
- [ ] Draw a complete free-body diagram
- [ ] Find the net force from multiple forces
- [ ] Identify equilibrium conditions

SCIENTIFIC WRITING AND EXAM SUPPORT

When answering questions from this lesson, separate:

- the physical quantity being discussed,
- the model or law being applied,
- the mathematical relationship, including units,
- the conclusion in words.

For explanation questions, write in the pattern: **claim -> physics reason -> consequence**. For calculation questions, state the formula, substitute with units, calculate, then interpret the answer.

MAINTENANCE LOOP

One-minute retrieval:

1. State the key law, model, or relationship used in this lesson.
2. Identify one common misconception that would lead to a wrong answer.
3. Write one sentence that links the calculation or evidence back to the physical meaning.

STUDENT WORKING