SCIENCE FOUNDATIONS

Drawing free-body diagrams

Difficulty level: Intermediate

Science Foundations

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Overview of the concept

This is how an engineer works out whether a bridge or a bookshelf will hold, by drawing every push and pull on it as an arrow before doing any maths. A builder checking a shelf bracket sketches the weight of the books and the pull of the screws before deciding if it is strong enough. A mechanic figuring out why a tow rope snapped starts by drawing the forces on the rope. The pull of a string or rope is called tension. Knowing free-body diagrams tells you which forces are really acting, so you can see what will hold and what will give way.



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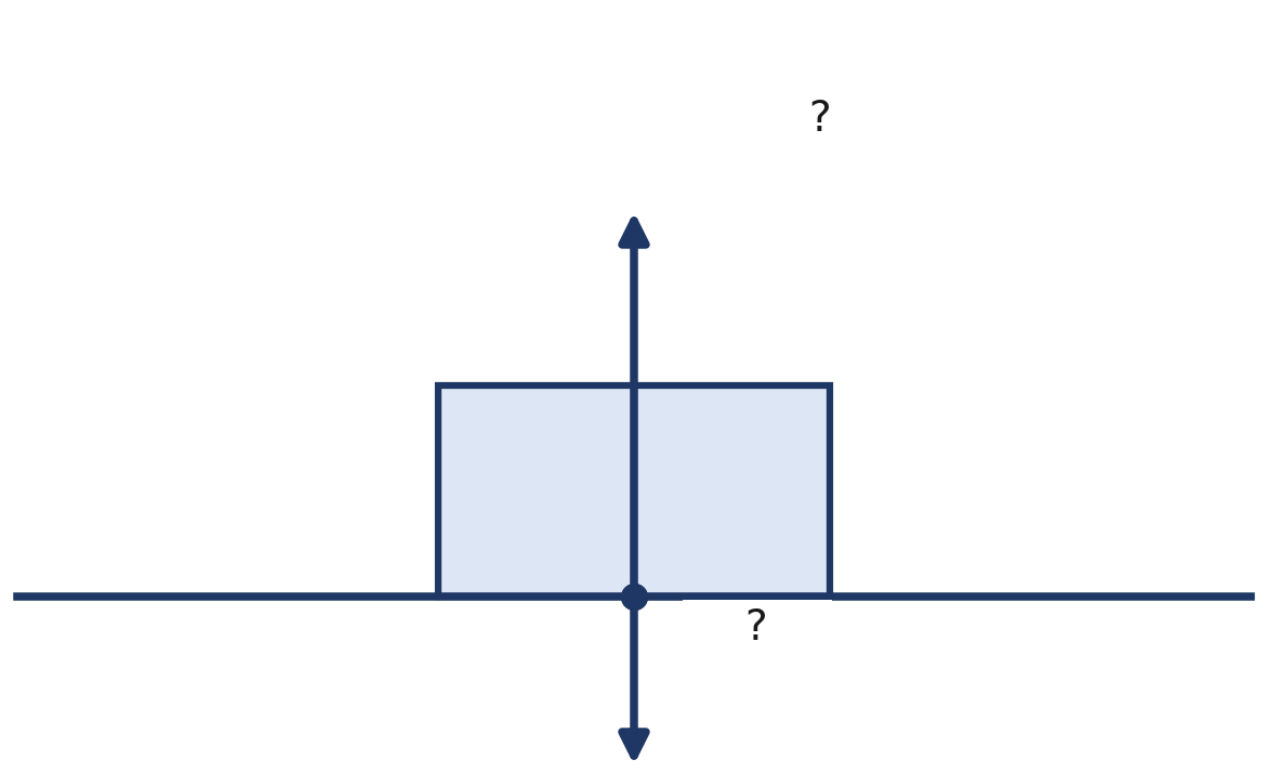
Worked examples

EXAMPLE 1

Q Draw the free-body diagram of a book resting on a table.



SOLUTION

Draw the book as a dot.

Add gravity arrow down, labelled weight, and normal arrow up, labelled normal force.

Make the arrows equal length: the book is not accelerating.

The result is two equal arrows, weight down, normal up.

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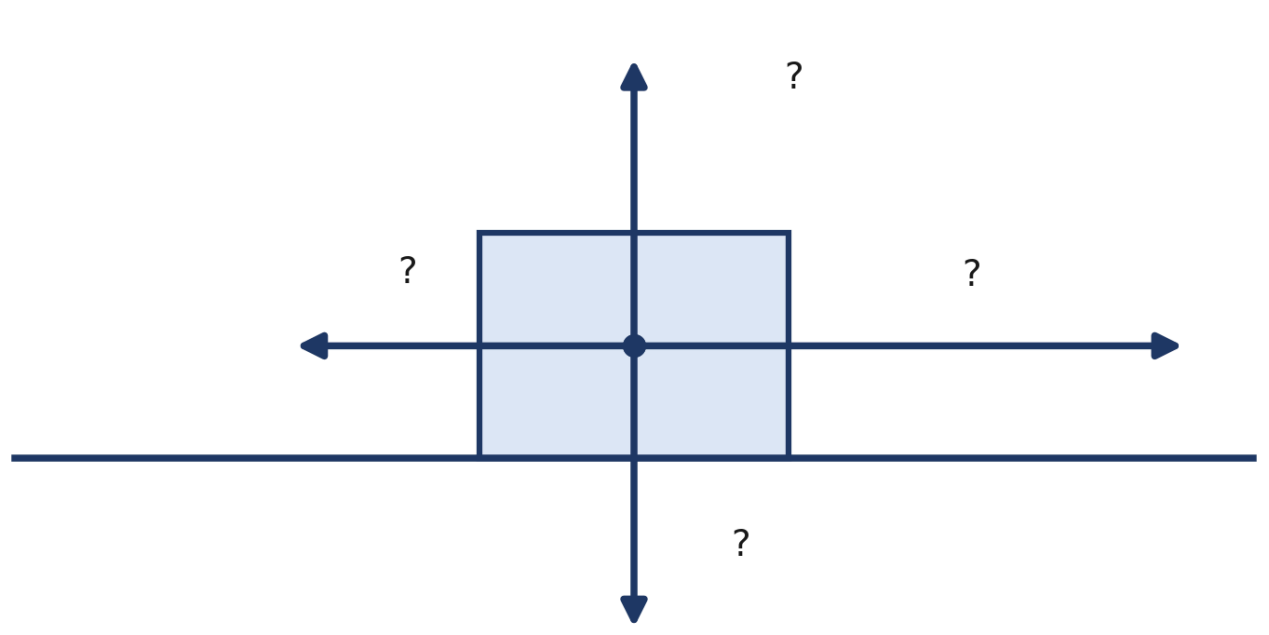
EXAMPLE 2

Q Draw the free-body diagram of a box sliding right with friction.



SOLUTION

Draw the box as a dot.

Add weight down, normal up, applied push right, friction left.

Make the friction arrow shorter than the push if it speeds up.

The result is four arrows, friction opposing motion.

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Practice questions

1 **Draw the free-body diagram of a book hanging from a string. Name each force arrow and its direction.**

- **A** Weight arrow up and tension arrow down, equal in length
- **B** Weight arrow down and tension arrow up, equal in length
- **C** Weight arrow down and normal force arrow up, equal in length
- **D** Weight arrow down only

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2

Draw the free-body diagram of a mug resting on a desk. Name each force arrow and its direction.

A. Weight arrow up and normal force arrow down, equal in length

B. Weight arrow down only

C. Weight arrow down and normal force arrow up, equal in length

D. Normal force arrow up only

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3

Draw the free-body diagram of a crate being pushed to the left across a floor with friction. Name each force arrow and its direction.

A. Weight down, normal force up, applied push to the left, friction to the right

B. Weight down, normal force up, applied push to the right, friction to the left

C. Weight up, normal force down, push to the left, friction to the left

D. Weight down, normal force up, push to the left only

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4 A box is pushed to the right across a floor but does not move. What does the friction arrow look like?

- **A** Friction arrow to the left, equal in length to the push
- **B** Friction arrow to the right, equal in length to the push
- **C** No friction arrow
- **D** Friction arrow to the left, shorter than the push

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5 First step of a free-body diagram?

- **A** Draw all the arrows first
- **B** Draw the object as a dot
- **C** Measure the mass
- **D** Draw the surface first

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6 Where do arrows start?

- A From the dot (the object)
- B From the surface
- C From the arrow tip
- D From the table edge

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7 Longer arrow means what?

- A Smaller force
- B Larger force
- C Longer distance
- D Faster speed

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8 Equal up and down arrows mean what?

- A The object is speeding up
- B The object is falling
- C No vertical acceleration
- D The weight is zero

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9 What force does a surface exert upward?

- A Gravity
- B Tension
- C Friction
- D Normal force

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10

Push right, friction left, push longer: what happens?

A It slows down to the right

B It stays still

C It speeds up to the right

D It speeds up to the left

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ANSWER KEY

1. Weight arrow down and tension arrow up, equal in length

2. Weight arrow down and normal force arrow up, equal in length

3. Weight down, normal force up, applied push to the left, friction to the right

4. Friction arrow to the left, equal in length to the push

5. Draw the object as a dot

6. From the dot (the object)

7. Larger force

8. No vertical acceleration

9. Normal force

10. It speeds up to the right

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