

Exercise walk-through

2.5

Newton's Second Law

AP Physics C: Mechanics

Free-body diagrams and Newton's laws

Draw every force on a **free-body diagram**, resolve into components, add to the **net force**.

The three laws

1st: inertia $\vec{F}_{net} = m\vec{a}$

3rd: equal-opposite pairs, different bodies



Rocket force

Worked example – two bodies, one string

A 6.0 kg cart on a frictionless table is pulled by a light string over a pulley to a hanging 2.0 kg mass. Find a and the tension.

- treat them as one system:

$$a = \frac{m_2 g}{m_1 + m_2} = \frac{(2.0)(9.8)}{8.0} = 2.45 \text{ m/s}^2$$

- then one body alone for T : cart,

$$T = m_1 a = 14.7 \text{ N}$$

- check with the hanging mass:

$$m_2 g - T = 19.6 - 14.7 = 4.9 = m_2 a \checkmark$$

The string constraint – same $|a|$, same $|T|$ – is what lets you do this. Solve for a with the whole system, then use one body to get an internal force.

Newton's laws, one axis at a time

third law

A pushes B, B pushes back equally and oppositely. The pair acts on **different objects**, so it never cancels inside one free-body diagram

second law

$$\sum \vec{F} = \frac{d\vec{p}}{dt} = m\vec{a} \text{ for constant mass – apply it one axis at a time}$$

when F depends on v

$m dv/dt = F(v)$ is a differential equation; separate and integrate

translational equilibrium

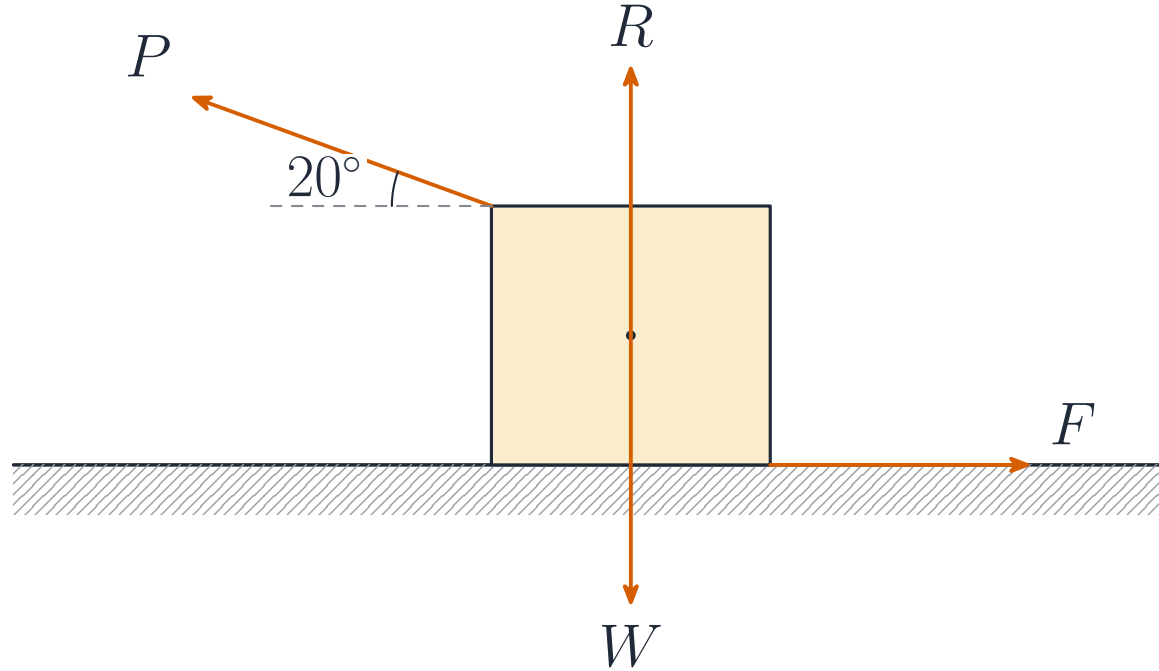
$$\sum \vec{F} = 0, \text{ so } \vec{a} = 0 \text{ – at rest or at constant velocity}$$

normal force

perpendicular to the surface; it is whatever it needs to be, and is not always mg

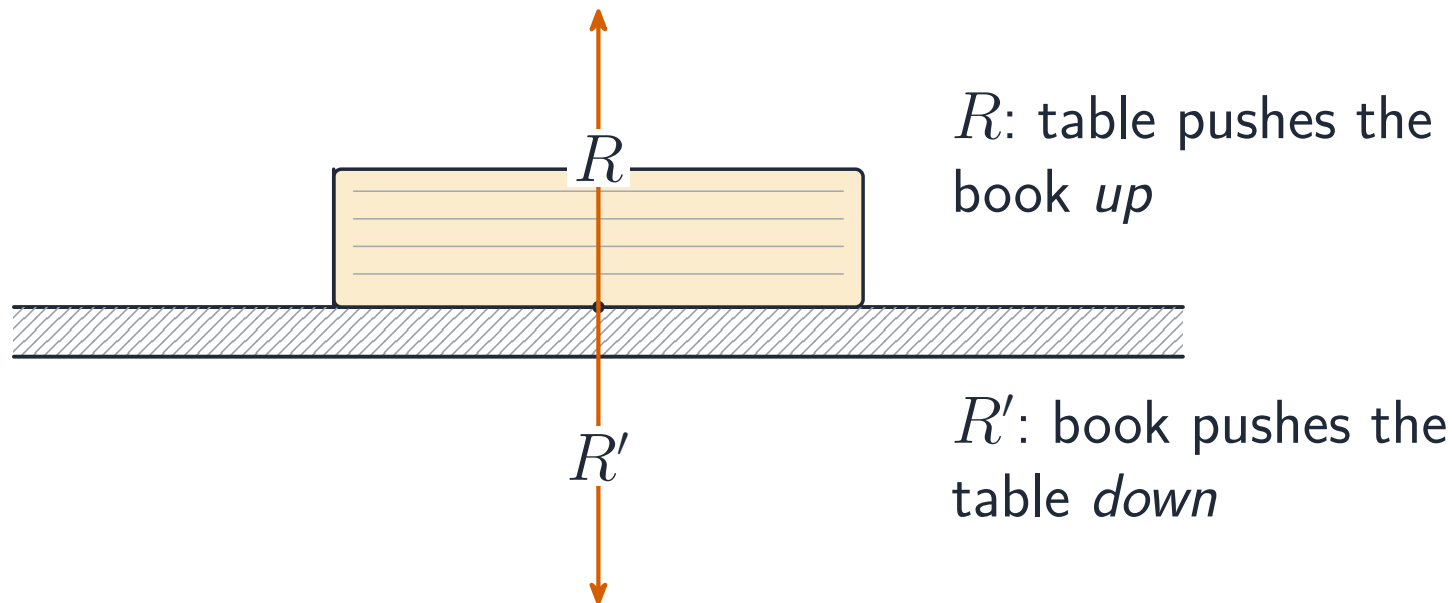
An action–reaction pair on one diagram is the commonest error in the unit. If both arrows are on the same body, one of them does not belong there.

Forces and Free-Body Diagrams



A free-body diagram shows every force acting on one object

A Newton's third-law pair



A Newton's third-law pair: equal and opposite forces on two different objects

Exercises 2.1-2.3

2.1 A net force of 18 N acts on a 6 kg mass. Find the acceleration. [2]

2.2 A 3 kg object accelerates at 4 m s^{-2} . Find the net force. [2]

2.3 A 10 N net force gives an acceleration of 2 m s^{-2} . Find the mass. [2]

Exercises 2.1·2.3

2.1 A net force of 18 N acts on a 6 kg mass. Find the acceleration. [2]

2.1

- $a = F/m = 18/6 = 3 \text{ m s}^{-2}$

2.2 A 3 kg object accelerates at 4 m s^{-2} . Find the net force. [2]

2.2

- $F = ma = 3 \times 4 = 12 \text{ N}$

2.3 A 10 N net force gives an acceleration of 2 m s^{-2} . Find the mass. [2]

2.3

- $m = F/a = 10/2 = 5 \text{ kg}$

Exercises 2.4·3.1

2.4 A 5 kg crate is pushed by 25 N against 10 N friction. Find the acceleration. [2]

3.1 For a fixed net force, doubling the mass [1]

☐

A doubles the acceleration

B halves the acceleration

C leaves the acceleration unchanged

D quadruples the acceleration

Exercises 2.4·3.1

2.4 A 5 kg crate is pushed by 25 N against 10 N friction. Find the acceleration. [2]

2.4

- $F_{net} = 25 - 10 = 15 \text{ N}$; $a = 15/5 = 3 \text{ m s}^{-2}$

3.1 For a fixed net force, doubling the mass [1]

☐

A doubles the acceleration

B halves the acceleration

C leaves the acceleration unchanged

D quadruples the acceleration

3.1 B

- $a = F/m$, so doubling m halves a

Exercise 3.2

3.2 A 2 kg ball has a net force of 6 N. Its acceleration is

[1]

☐

A 12 m s^{-2}

B 3 m s^{-2}

C 8 m s^{-2}

D 0.33 m s^{-2}

Exercise 3.2

3.2 A 2 kg ball has a net force of 6 N. Its acceleration is

[1]

☐

A 12 m s^{-2}

B 3 m s^{-2}

C 8 m s^{-2}

D 0.33 m s^{-2}

3.2 B

- $a = 6/2 = 3 \text{ m s}^{-2}$

Exercise 3.3 (a)

3.3 A 1200 kg car speeds up at 2.5 m s^{-2} .

(a) Find the net driving force.

[2]

Exercise 3.3 (a)

3.3 A 1200 kg car speeds up at 2.5 m s^{-2} .

(a) Find the net driving force.

[2]

(a)

- $F = ma = 1200 \times 2.5 = 3000 \text{ N}$

Exercise 3.3 (b)

3.3 A 1200 kg car speeds up at 2.5 m s^{-2} .

(b) State what happens to the acceleration if the same force acts on a heavier car. [1]

Exercise 3.3 (b)

3.3 A 1200 kg car speeds up at 2.5 m s^{-2} .

(b) State what happens to the acceleration if the same force acts on a heavier car. [1]

(b)

- It decreases (more mass, less acceleration for the same force)

Exercise 3.4 (a)

3.4 A 2 kg block on a frictionless surface is pulled by two horizontal forces: 12 N right and 4 N left.

(a) Find the net force.

[1]

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3.4 A 2 kg block on a frictionless surface is pulled by two horizontal forces: 12 N right and 4 N left.

(a) Find the net force.

[1]

(a)

- $12 - 4 = 8 \text{ N}$

Exercise 3.4 (b)

3.4 A 2 kg block on a frictionless surface is pulled by two horizontal forces: 12 N right and 4 N left.

(b) Find the acceleration.

[2]

Exercise 3.4 (b)

3.4 A 2 kg block on a frictionless surface is pulled by two horizontal forces: 12 N right and 4 N left.

(b) Find the acceleration.

[2]

(b)

- $a = 8/2 = 4 \text{ m s}^{-2}$