

Exercise walk-through

2.4

Newton's First 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

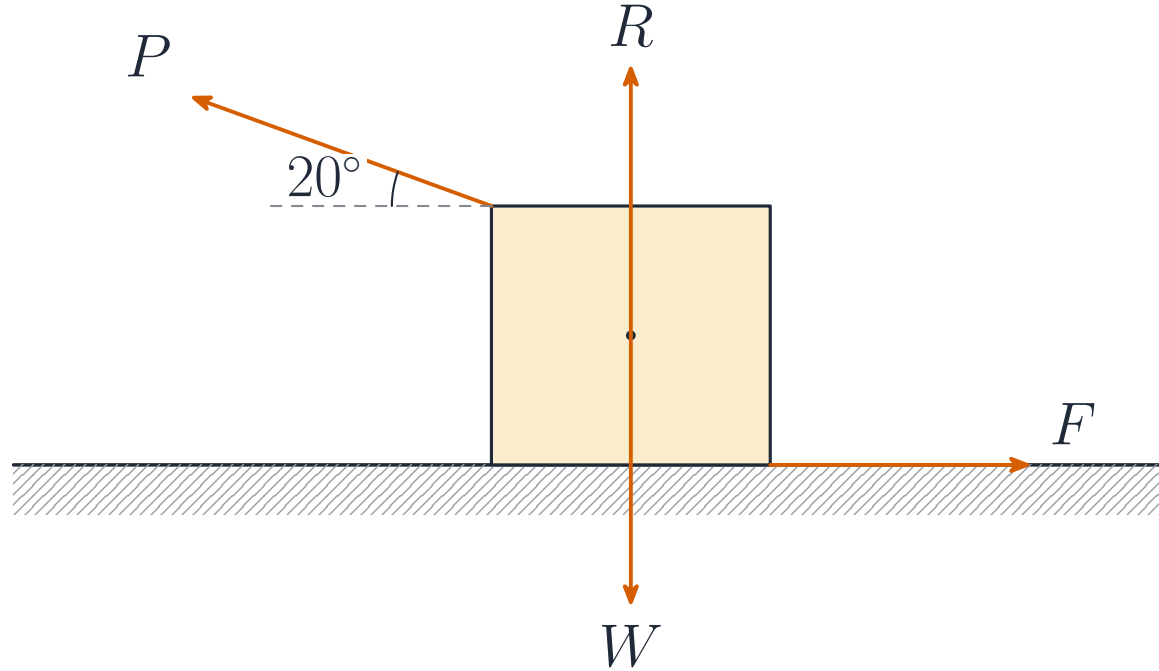
$$\sum \vec{F} = 0, \text{ so } \vec{a} = 0 - \text{at rest or at constant velocity}$$

normal force

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

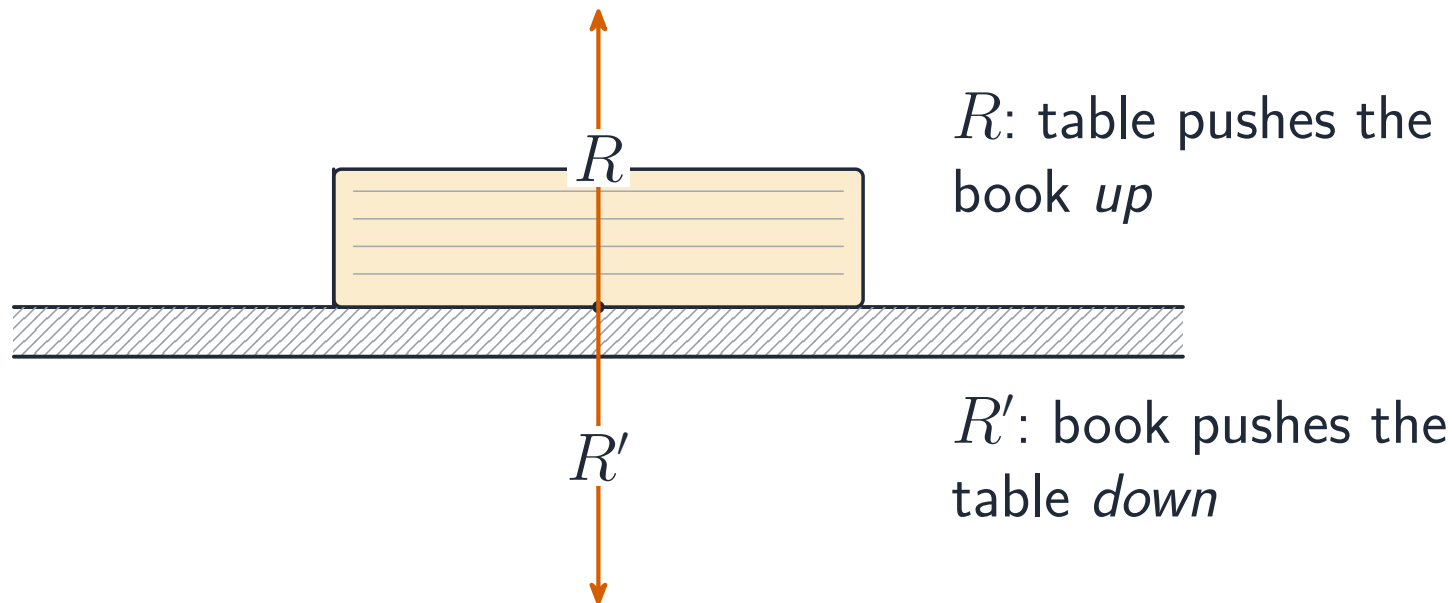
An action–reaction pair on one diagram is the commonest error in the unit. If both arrows are on the same body, one of them does not belong there.

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 State what happens to a moving object when no net force acts on it. [1]

2.2 Define inertia in one sentence. [1]

2.3 A crate moves at constant velocity. State the net force on it. [1]

Exercises 2.1-2.3

2.1 State what happens to a moving object when no net force acts on it. [1]

2.1

- It keeps moving at constant velocity in a straight line
-

2.2 Define inertia in one sentence. [1]

2.2

- Inertia is an object's resistance to a change in its motion
-

2.3 A crate moves at constant velocity. State the net force on it. [1]

2.3

- Zero (it is in equilibrium)

Exercises 2.4·3.1

2.4 Which has more inertia: a 1 kg ball or a 10 kg ball? [1]

3.1 An object moves at constant velocity. The net force on it is [1]

☐

A in the direction of motion

B opposite to the motion

C zero

D equal to its weight

Exercises 2.4·3.1

2.4 Which has more inertia: a 1 kg ball or a 10 kg ball? [1]

2.4

- The 10 kg ball (more mass, more inertia)

3.1 An object moves at constant velocity. The net force on it is [1]

☐

A in the direction of motion

B opposite to the motion

C zero

D equal to its weight

3.1 C

- constant velocity means zero net force

Exercise 3.2

3.2 Inertia depends on an object's

[1]

☐

A velocity

B mass

C colour

D position

Exercise 3.2

3.2 Inertia depends on an object's

[1]

☐

A velocity

B mass

C colour

D position

3.2 B

- inertia depends on mass

Exercise 3.3 (a)

3.3 A hovering drone stays perfectly still in mid-air.

(a) State the net force on it.

[1]

Exercise 3.3 (a)

3.3 A hovering drone stays perfectly still in mid-air.

(a) State the net force on it.

[1]

(a)

- Zero

Exercise 3.3 (b)

3.3 A hovering drone stays perfectly still in mid-air.

(b) Name the two forces that must balance.

[2]

Exercise 3.3 (b)

3.3 A hovering drone stays perfectly still in mid-air.

(b) Name the two forces that must balance.

[2]

(b)

- Weight (down) and the upward lift/thrust (up)

Exercise 3.4 (a)

3.4 A passenger lurches forward when a bus suddenly brakes.

(a) Explain this using inertia.

[2]

Exercise 3.4 (a)

3.4 A passenger lurches forward when a bus suddenly brakes.

(a) Explain this using inertia.

[2]

(a)

- The passenger's inertia keeps them moving forward while the bus decelerates beneath them

Exercise 3.4 (b)

3.4 A passenger lurches forward when a bus suddenly brakes.

(b) State whether a force pushes the passenger forward.

[1]

Exercise 3.4 (b)

3.4 A passenger lurches forward when a bus suddenly brakes.

(b) State whether a force pushes the passenger forward.

[1]

(b)

- No – no forward force acts; it is the absence of one