

Exercise walk-through

2.3

Newton's Third 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

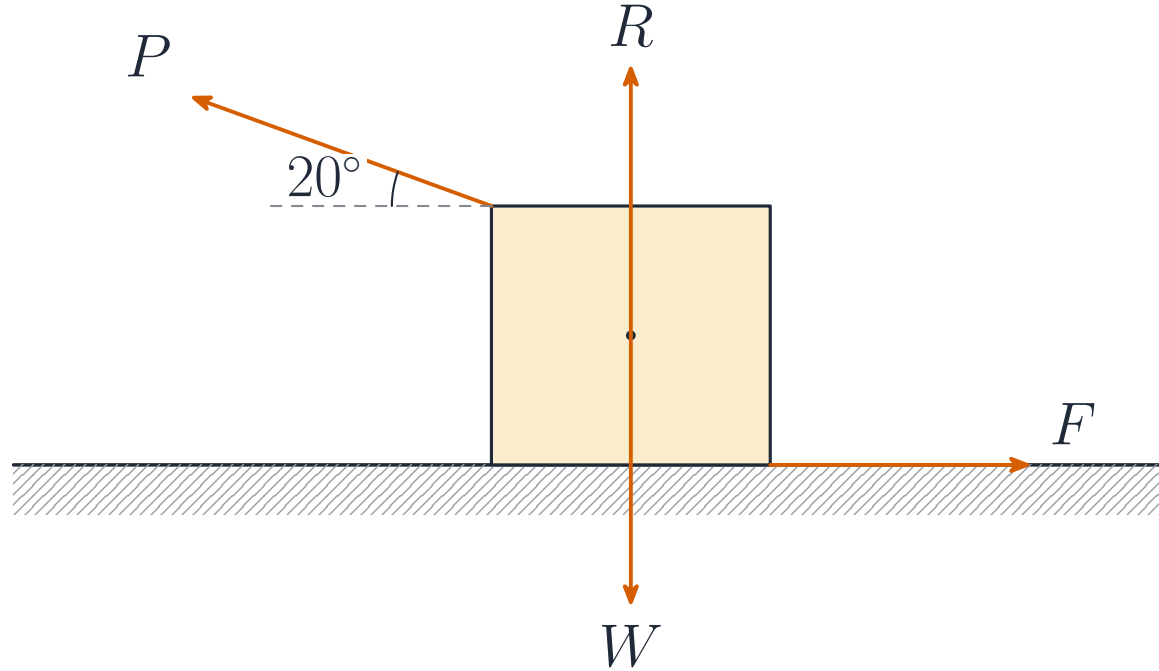
$$\sum \vec{F} = 0, \text{ so } \vec{a} = 0 - \text{at rest or at constant velocity}$$

normal force

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

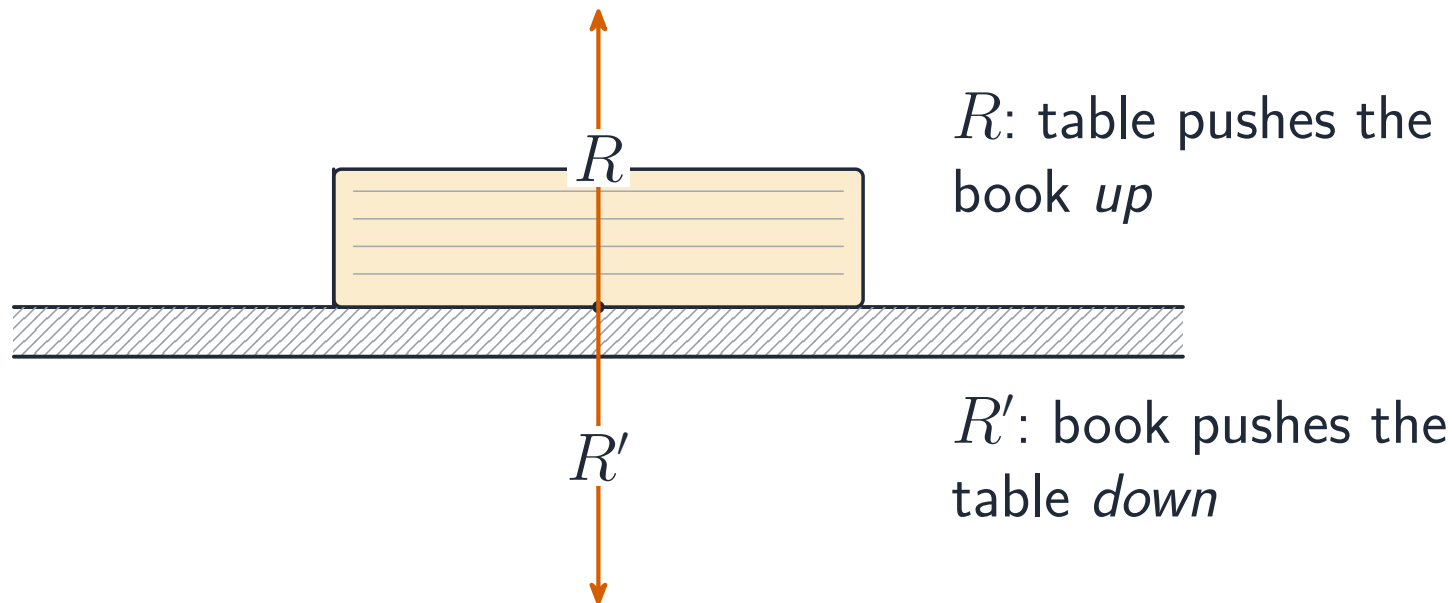
An action–reaction pair on one diagram is the commonest error in the unit. If both arrows are on the same body, one of them does not belong there.

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 hammer hits a nail with 50 N. State the force the nail exerts on the hammer. [1]

2.2 State the two properties an action-reaction pair always shares. [2]

2.3 Why do action and reaction forces not cancel each other out? [1]

Exercises 2.1-2.3

2.1 A hammer hits a nail with 50 N. State the force the nail exerts on the hammer. [1]

2.1

- 50 N in the opposite direction (back on the hammer)
-

2.2 State the two properties an action-reaction pair always shares. [2]

2.2

- Equal in size and opposite in direction (and they act on different objects)
-

2.3 Why do action and reaction forces not cancel each other out? [1]

2.3

- They act on different objects, so they never appear together on one free-body diagram

Exercises 2.4-3.1

2.4 When you walk forward, what pushes you forward? [1]

3.1 Newton's third law says forces come in pairs that are [1]

☐

A equal and in the same direction

B equal and opposite, on the same object

C equal and opposite, on different objects

D unequal and opposite

Exercises 2.4·3.1

2.4 When you walk forward, what pushes you forward? [1]

2.4

- The ground pushes you forward (the reaction to your foot pushing back on it)

3.1 Newton's third law says forces come in pairs that are [1]

☐

A equal and in the same direction

B equal and opposite, on the same object

C equal and opposite, on different objects

D unequal and opposite

3.1 C

- equal and opposite, on different objects

Exercise 3.2

3.2 A car tyre pushes back on the road with 2000 N. The road pushes the tyre forward with [1]

☐

A 0 N

B 1000 N

C 2000 N

D 4000 N

Exercise 3.2

3.2 A car tyre pushes back on the road with 2000 N. The road pushes the tyre forward with [1]

☐

A 0 N

B 1000 N

C 2000 N

D 4000 N

3.2 C

- the reaction is equal, 2000 N

Exercise 3.3 (a)

3.3 A book of weight 8 N rests on a table.

(a) State the reaction to the Earth's gravitational pull on the book.

[1]

Exercise 3.3 (a)

3.3 A book of weight 8 N rests on a table.

(a) State the reaction to the Earth's gravitational pull on the book.

[1]

(a)

- The book's gravitational pull on the Earth, equal and upward

Exercise 3.3 (b)

3.3 A book of weight 8 N rests on a table.

(b) Explain why this is *not* the normal force from the table.

[1]

Exercise 3.3 (b)

3.3 A book of weight 8 N rests on a table.

(b) Explain why this is *not* the normal force from the table. [1]

(b)

- The normal force acts on the book from the table, a different pair; the reaction to gravity acts on the Earth

Exercise 3.4 (a)

3.4 A swimmer pushes water backward to move forward.

(a) Identify the action-reaction pair.

[2]

Exercise 3.4 (a)

3.4 A swimmer pushes water backward to move forward.

(a) Identify the action-reaction pair.

[2]

(a)

- The swimmer pushes water back; the water pushes the swimmer forward

Exercise 3.4 (b)

3.4 A swimmer pushes water backward to move forward.

(b) State which force of the pair moves the swimmer.

[1]

Exercise 3.4 (b)

3.4 A swimmer pushes water backward to move forward.

(b) State which force of the pair moves the swimmer.

[1]

(b)

- The forward push of the water on the swimmer