

Newton's second law: net force and acceleration

Physics · Year 11 · Starting

Use the worked examples and teaching notes to guide the lesson. Each practice answer and its full working appear beside the question.

Take the time you need. Complete each phase and revisit any step you cannot yet explain.

Get ready

Learning goal

Use forces on one constant-mass object to calculate and explain horizontal acceleration.

- Combine forces with a stated direction convention.
- Select and rearrange $F = ma$ for the required quantity.
- Find a required push when an opposing force acts.
- Explain balanced forces and the direction of acceleration.

The idea in context

Two carts can have different pushes but the same acceleration. Compare their net forces and masses.

Before you begin

Equality and inverse operations

Rightwards can be positive and leftwards negative. Add signed forces. An equation stays equal when the same valid operation is performed on both sides.

net force: The combined effect of all forces acting on the same object.

acceleration: Change in velocity per second; its direction follows net force.

Watch the prerequisite 1

Solve $2x - 10 = 6$.

Step 1

Before: $2x - 10 = 6$

Action: Add ten to both sides.

After: $2x - 10 + 10 = 6 + 10$; $2x = 16$

Why: The opposite terms sum to zero.

$$\begin{array}{rcl} 2x - 10 & = & 6 \\ +10 & & +10 \\ \hline \end{array}$$

$$2x \quad \quad \quad \cancel{-10} \quad \quad \quad \cancel{+10} \quad \quad = \quad 16$$

Opposite terms sum to zero.

$$2x \quad \quad = \quad \quad 16$$

Apply +10 to both sides

$2x - 10$ equals 6. Apply +10 to each side. Result: $2x$ equals 16. The marked opposite terms sum to zero.

Step 2

Before: $2x = 16$

Action: Divide both sides by two.

After: $2x/2 = 16/2$; $x = 8$

Why: The matching factor two reduces to one.

$$\frac{2x}{2} = \frac{16}{2}$$

Apply the same action to both sides.

$$x = 8$$

Apply /2 to both sides

$2x$ equals 16. Apply /2 to each side. Result: x equals 8.

Step 3

Before: $x = 8$

Action: Substitute into the original equation.

After: $2 \times 8 - 10 = 16 - 10 = 6$

Why: The original equation is satisfied.

$x = 8$. Both operations preserve equality.

Complete the missing step 1

Complete: $3y - 6 = 9$. Add the same quantity to both sides, then divide both sides.

Hint 1: Use equal operations to isolate the unknown.

Hint 2: Add six to both sides: $3y - 6 + 6 = 9 + 6$.

Hint 3: Now $3y = 15$. Divide both sides by three; simplify the unknown.

$3y - 6 + 6 = 9 + 6$; $3y = 15$. Divide both sides by 3: $y = 5$. Check: $3 \times 5 - 6 = 9$.

Try a fresh question 1

Solve $4z + 3 = 19$ and check.

Hint 1: Use the same operation on both sides.

Hint 2: Subtract three from both sides.

Hint 3: $4z = 16$. Divide both sides by four, then check in the original equation.

Subtract 3 from both sides: $4z + 3 - 3 = 19 - 3$; $4z = 16$. Divide both sides by 4: $z = 4$. Check: $4 \times 4 + 3 = 19$.

Signed quantities and opposing forces

A chosen direction gives positive and negative contributions. Same-direction forces add; opposing directions subtract in magnitude. Keep the direction of the larger contribution.

positive direction: The direction chosen to give positive signed components; the opposite direction is negative.

Watch the prerequisite 1

Combine 9 N rightwards and 5 N leftwards.

Step 1

Before: The forces oppose each other.

Action: Choose rightwards positive.

After: Rightward force +9 N; leftward force -5 N

Why: The signs describe directions, not different kinds of force.

Step 2

Before: $F = (+9) + (-5)$

Action: Add the signed contributions.

After: $F = 9 - 5 = +4 \text{ N}$

Why: Five opposing units balance; four rightward units remain.

Right: 9 units; left: 5 units

$$9 - 5 = 4$$

Net force: 4 N rightwards

Combine opposite directions

Right: 9 units; left: 5 units $9 - 5 = 4$ Net force: 4 N rightwards

Step 3

Before: Net effect 4 N rightwards.

Action: Compare with the original directions.

After: The larger original force points right.

Why: The result direction agrees. Both original forces still act.

4 N rightwards.

Complete the missing step 1

Complete the signed sum for 7 N right and 3 N left: $F = (+__) + (-__)$.

Hint 1: Use direction signs before arithmetic.

Hint 2: The rightward force is positive and leftward force negative.

Hint 3: Write $7 - 3$ and subtract; the sign gives direction.

Right positive: $F = (+7) + (-3) = 7 - 3 = +4 \text{ N}$; 4 N rightwards.

Try a fresh question 1

Combine 2 N right and 8 N left using rightwards positive.

Hint 1: Use the signed direction convention.

Hint 2: Write the sum $(+2) + (-8)$.

Hint 3: The leftward magnitude is greater; subtract and state the direction.

$F = (+2) + (-8) = 2 - 8 = -6 \text{ N}$; the net effect is 6 N leftwards.

Division, mass, force and acceleration units

Mass is measured in kg, force in N and acceleration in m s^{-2} . One newton is kg m s^{-2} . Dividing net force by mass gives acceleration, not speed.

mass: A measure of inertia, measured in kilograms.

force: A push or pull, measured in newtons.

velocity: Speed together with direction, measured in metres per second.

Watch the prerequisite 1

Explain and calculate 12 N divided by 3 kg.

Step 1

Before: 12 divided among three equal groups.

Action: Divide twelve by three.

After: $12/3 = 4$

Why: Three groups of four reconstruct twelve.

12 units

Group 1: 4; group 2: 4; group 3: 4

$3 \times 4 = 12$

Division into equal groups

12 units Group 1: 4; group 2: 4; group 3: 4 $3 \times 4 = 12$

Step 2

Before: One newton is one kg m s^{-2} .

Action: Replace the newton unit with its definition.

After: $12 \text{ N}/3 \text{ kg} = (12 \text{ kg m s}^{-2})/(3 \text{ kg})$

Why: Numerical division and unit division are separate.

Step 3

Before: $(12 \text{ kg m s}^{-2})/(3 \text{ kg})$

Action: Divide numbers and reduce matching kilogram factors.

After: $(12/3)(\text{kg/kg}) \text{ m s}^{-2} = 4 \text{ m s}^{-2}$

Why: Kilogram divided by kilogram is one. The acceleration unit remains.

4 m s^{-2} .

Complete the missing step 1

Complete $(10 \text{ N})/(2 \text{ kg}) = (10/2)(\text{kg/kg}) \text{ m s}^{-2}$ and name the quantity.

Hint 1: Separate numerical division from unit division.

Hint 2: Replace N with kg m s^{-2} .

Hint 3: Divide ten by two and reduce the matching kilogram factors.

$10/2 = 5$; $\text{kg/kg} = 1$. Therefore $10 \text{ N}/2 \text{ kg} = 5 \text{ m s}^{-2}$. This is acceleration, a change of velocity each second.

Try a fresh question 1

Calculate $(6 \text{ N})/(4 \text{ kg})$. Explain its unit and whether the result must be a whole number.

Hint 1: Use numerical and unit division.

Hint 2: Write $(6/4)(\text{kg/kg}) \text{ m s}^{-2}$.

Hint 3: Reduce the kilogram ratio to one and complete the numerical quotient.

$6/4 = 1.5$ and $\text{kg/kg} = 1$; result 1.5 m s^{-2} . Acceleration need not be a whole number. This is not speed, which has unit m s^{-1} .

Starting-point question 1

Which equal operation removes -4 in $y - 4 = 7$?

Answer and working

Add four to both sides.

Starting-point question 2

What isolates y in $3y = 12$?

Answer and working

Divide both sides by three; $y = 4$.

Starting-point question 3

Combine $+9 \text{ N}$ and -5 N .

Answer and working

$+4 \text{ N}$ rightwards.

Starting-point question 4

Combine 3 N right and 7 N left.

Answer and working

4 N leftwards.

Starting-point question 5

What is $12/3$?

Answer and working

4.

Starting-point question 6

Does m s^{-2} describe velocity or acceleration?

Answer and working

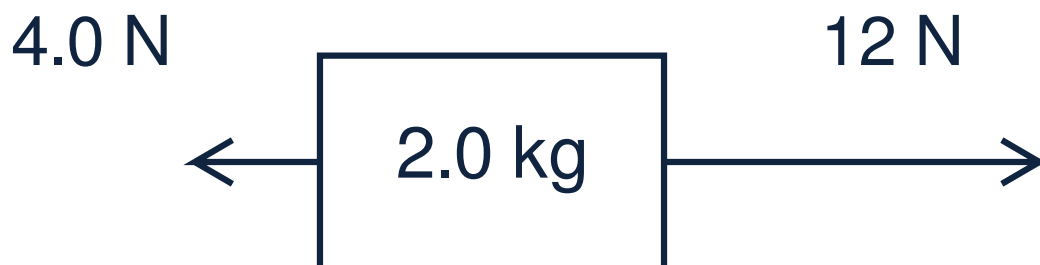
Acceleration.

Watch — I do

Find the force that belongs in the equation

Study one trolley. Choose rightwards positive. Include every horizontal force. The upward support force balances weight in this level-surface model. The diagram is schematic.

F = sum of signed horizontal forces



Rightwards positive.

Arrow lengths use the same force scale.

Horizontal forces on one trolley

A 2.0 kilogram trolley has 12 newtons rightwards and 4.0 newtons leftwards. Upward support balances downward weight. Only the horizontal forces are shown. Arrow lengths are proportional to force magnitude within this diagram.

Use Newton's second law

For constant mass in this horizontal model, F denotes the signed horizontal net force. Acceleration has the same direction as F . Mass is in kilograms; force in newtons; acceleration in metres per second squared.

$$F = ma$$

$$a = F/m$$

$$\frac{F}{m} = \frac{m \times a}{m}$$

$$\frac{F}{m} = \frac{\cancel{m} \times a}{\cancel{m}}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Select the equation for the unknown

Find net force first. If a push P acts rightwards against resistance R , $P - R = ma$. Add R to both sides to find P . This arrangement determines the signs.

$$P - R = ma$$

$$P - R + R = ma + R$$

$$P = ma + R$$

$$\begin{array}{rcl}
 P - 3 & = & 8 \\
 +3 & & +3 \\
 \hline
 P & \overset{=3}{\cancel{-3}} & \overset{+3}{\cancel{+3}} = 11
 \end{array}$$

Opposite terms sum to zero.

$$P = 11$$

Apply +3 to both sides

$P - 3$ equals 8. Apply +3 to each side. Result: P equals 11. The marked opposite terms sum to zero.

Acceleration is a change in velocity

A negative acceleration points left under our convention. Whether speed rises or falls also depends on velocity direction. Zero net force gives zero acceleration and unchanged velocity, including a possible nonzero velocity.

$F = 0 \Rightarrow a = 0$; velocity remains unchanged

v right, a right: speed increases

v left, a right: speed decreases initially

a zero: velocity stays unchanged

Compare velocity and acceleration

v right, a right: speed increases v left, a right: speed decreases initially a zero: velocity stays unchanged

Watch — worked models

Follow the model

A 2.0 kg trolley has 12.0 N rightwards and 4.0 N leftwards. Find acceleration.

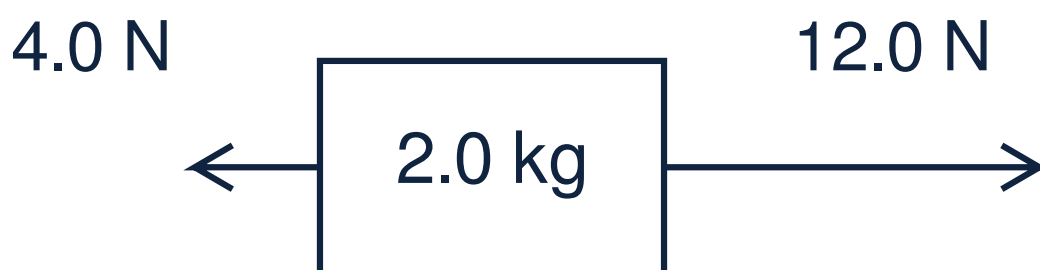
Step 1

Before: One trolley on a level surface.

Action: Draw and label the forces.

After: Mass 2.0 kg; horizontal forces 12.0 N and 4.0 N.

Why: Support balances weight; only horizontal motion is considered.



Rightwards positive.

Arrow lengths use the same force scale.

Horizontal forces on one trolley

A 2.0 kilogram trolley has 12.0 newtons rightwards and 4.0 newtons leftwards. Upward support balances downward weight. Only the horizontal forces are shown. Arrow lengths are proportional to force magnitude within this diagram.

Step 2

Before: 12.0 N right; 4.0 N left.

Action: Choose rightwards positive.

After: $F = +12.0 + (-4.0) = 8.0 \text{ N}$

Why: Signs record direction. Net force is a combined effect, not an extra force.

Step 3

Before: $F = ma$

Action: Divide both sides by mass.

After: $F/m = ma/m$; $a = F/m$

Why: Mass divided by itself is one; acceleration remains.

$$\frac{F}{m} = \frac{m \times a}{m}$$

$$\frac{F}{m} = \frac{\cancel{m} \times a}{\cancel{m}}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 4

Before: $a = F/m$

Action: Substitute net force and mass.

After: $a = 8.0/2.0 = 4.0 \text{ m s}^{-2}$

Why: The acceleration is 4.0 m s^{-2} rightwards.

Step 5

Before: $a = 4.0 \text{ m s}^{-2}$

Action: Check force and units.

After: $ma = 2.0 \times (4.0) = 8.0 \text{ N}$

Why: The force agrees; N/kg equals metres per second squared.

4.0 m s^{-2} rightwards.

Follow the model

A 2.0 kg trolley has 4.0 N rightwards and 10.0 N leftwards. Find acceleration.

Step 1

Before: One trolley on a level surface.

Action: Draw and label the forces.

After: Mass 2.0 kg; horizontal forces 4.0 N and 10.0 N.

Why: Support balances weight; only horizontal motion is considered.



Rightwards positive.

Arrow lengths use the same force scale.

Horizontal forces on one trolley

A 2.0 kilogram trolley has 4.0 newtons rightwards and 10.0 newtons leftwards. Upward support balances downward weight. Only the horizontal forces are shown. Arrow lengths are proportional to force magnitude within this diagram.

Step 2

Before: 4.0 N right; 10.0 N left.

Action: Choose rightwards positive.

After: $F = +4.0 + (-10.0) = -6.0 \text{ N}$

Why: Signs record direction. Net force is a combined effect, not an extra force.

Step 3

Before: $F = ma$

Action: Divide both sides by mass.

After: $F/m = ma/m$; $a = F/m$

Why: Mass divided by itself is one; acceleration remains.

$$\frac{F}{m} = \frac{m \times a}{m}$$

$$\frac{F}{m} = \frac{\cancel{m} \times a}{\cancel{m}}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 4

Before: $a = F/m$

Action: Substitute net force and mass.

After: $a = -6.0/2.0 = -3.0 \text{ m s}^{-2}$

Why: The acceleration is 3.0 m s^{-2} leftwards.

Step 5

Before: $a = -3.0 \text{ m s}^{-2}$

Action: Check force and units.

After: $ma = 2.0 \times (-3.0) = -6.0 \text{ N}$

Why: The force agrees; N/kg equals metres per second squared.

3.0 m s^{-2} leftwards.

Follow the model

A 4.0 kg trolley needs 2.0 m s^{-2} rightwards acceleration against 3.0 N leftwards resistance. Find the rightward push.

Step 1

Before: Unknown push P; known mass and acceleration.

Action: Find the required net force first.

After: $F = ma = 4.0 \times 2.0 = 8.0 \text{ N}$

Why: The required net force differs from the push because resistance also acts.

Step 2

Before: P rightwards; 3.0 N leftwards.

Action: Write the signed force equation.

After: $P - 3.0 = 8.0$

Why: Rightwards is positive.

Step 3

Before: $P - 3.0 = 8.0$

Action: Add 3.0 to both sides.

After: $P - 3.0 + 3.0 = 8.0 + 3.0$; $P = 11.0 \text{ N}$

Why: The opposite resistance terms sum to zero.

$$\begin{array}{rcl} P - 3 & = & 8 \\ +3 & & +3 \\ \hline P & = & 11 \end{array}$$

Opposite terms sum to zero.

P = 11

Apply +3 to both sides

$P - 3$ equals 8. Apply +3 to each side. Result: P equals 11. The marked opposite terms sum to zero.

Step 4

Before: $P = 11.0 \text{ N}$

Action: Subtract resistance and divide by mass.

After: $(11.0 - 3.0)/4.0 = 2.0 \text{ m s}^{-2}$

Why: The requested acceleration is recovered.

Push 11.0 N rightwards.

Follow the model

A 3.0 kg trolley needs 2.0 m s^{-2} rightwards acceleration against 1.0 N leftwards resistance. Find the rightward push.

Step 1

Before: Unknown push P; known mass and acceleration.

Action: Find the required net force first.

After: $F = ma = 3.0 \times 2.0 = 6.0 \text{ N}$

Why: The required net force differs from the push because resistance also acts.

Step 2

Before: P rightwards; 1.0 N leftwards.

Action: Write the signed force equation.

After: $P - 1.0 = 6.0$

Why: Rightwards is positive.

Step 3

Before: $P - 1.0 = 6.0$

Action: Add 1.0 to both sides.

After: $P - 1.0 + 1.0 = 6.0 + 1.0$; $P = 7.0 \text{ N}$

Why: The opposite resistance terms sum to zero.

$$\begin{array}{rcl}
 P - 1 & = & 6 \\
 + 1 & & + 1 \\
 \hline
 P & \overset{=1}{-1} & \overset{+1}{-1} = 7
 \end{array}$$

Opposite terms sum to zero.

$$P = 7$$

Apply +1 to both sides

$P - 1$ equals 6. Apply +1 to each side. Result: P equals 7. The marked opposite terms sum to zero.

Step 4

Before: $P = 7.0 \text{ N}$

Action: Subtract resistance and divide by mass.

After: $(7.0 - 1.0)/3.0 = 2.0 \text{ m s}^{-2}$

Why: The requested acceleration is recovered.

Push 7.0 N rightwards.

Follow the model

A net force of 9.0 N rightwards gives acceleration 3.0 m s⁻² rightwards. Find mass.

Step 1

Before: $F = ma$

Action: Divide both sides by nonzero acceleration.

After: $F/a = ma/a$; $m = F/a$

Why: The factor a/a reduces to one.

$$\frac{F}{a} = \frac{m \times a}{a}$$

$$\frac{F}{a} = \frac{m \times \cancel{a}}{\cancel{a}}$$

$a/a = 1$; m remains.

$$m = F/a$$

Divide both sides by a ; matching factors reduce to one

F equals m times a . Divide both sides by a . The numerator and denominator factors a reduce to one; m remains. m equals F divided by a . The divisor must be nonzero.

Step 2

Before: $m = F/a$

Action: Substitute.

After: $m = 9.0/3.0 = 3.0$ kg

Why: Matching force and acceleration directions give positive mass.

Step 3

Before: $m = 3.0 \text{ kg}$

Action: Multiply mass by acceleration.

After: $3.0 \times 3.0 = 9.0 \text{ N}$

Why: This matches net force. If acceleration and net force are both zero, they cannot determine mass.
 3.0 kg .

Follow the model

A net force of 12 N leftwards produces acceleration 4.0 m s^{-2} leftwards. Find mass.

Step 1

Before: Force and acceleration point left.

Action: Choose rightwards positive.

After: $F = -12 \text{ N}$; $a = -4.0 \text{ m s}^{-2}$

Why: Both quantities use the same sign convention.

Step 2

Before: $F = ma$

Action: Divide both sides by nonzero a .

After: $F/a = ma/a$; $m = F/a$

Why: The matching acceleration factor reduces to one.

$$\frac{F}{a} = \frac{m \times a}{a}$$

$a/a = 1$; m remains.

$$m = F/a$$

Divide both sides by a ; matching factors reduce to one

F equals m times a . Divide both sides by a . The numerator and denominator factors a reduce to one; m remains. m equals F divided by a . The divisor must be nonzero.

Step 3

Before: $m = F/a$

Action: Substitute both signed values.

After: $m = (-12)/(-4.0) = 3.0 \text{ kg}$

Why: A negative divided by a negative is positive; direction does not create negative mass.

Step 4

Before: $m = 3.0 \text{ kg}$

Action: Multiply by signed acceleration.

After: $ma = 3.0 \times (-4.0) = -12 \text{ N}$

Why: The result reproduces the leftward net force.

3.0 kg.

Follow the model

A trolley already moves rightwards at 3.0 m s^{-1} . Opposing forces are each 6.0 N. Describe motion.

Step 1

Before: +6.0 N and -6.0 N

Action: Add signed forces.

After: $F = 6.0 - 6.0 = 0 \text{ N}$

Why: Forces balance.

Step 2

Before: $a = F/m$

Action: Use zero net force.

After: $a = 0/m = 0 \text{ m s}^{-2}$

Why: Any positive mass gives zero acceleration.

Step 3

Before: Initial velocity 3.0 m s^{-1} rightwards.

Action: Keep velocity unchanged.

After: Velocity remains 3.0 m s^{-1} rightwards.

Why: Zero acceleration does not imply zero velocity.

Constant velocity 3.0 m s^{-1} rightwards while forces remain balanced.

Follow the model

A stationary trolley has opposing horizontal forces each 8.0 N. Describe its motion while they stay balanced.

Step 1

Before: Initial velocity is zero; forces +8.0 N and -8.0 N.

Action: Add the signed forces.

After: $F = 8.0 - 8.0 = 0 \text{ N}$

Why: The two forces balance.

Step 2

Before: $a = F/m$ for positive mass.

Action: Use the net force zero.

After: $a = 0/m = 0 \text{ m s}^{-2}$

Why: There is no change in velocity.

Step 3

Before: Initial velocity zero; acceleration zero.

Action: Keep the initial velocity.

After: The trolley remains stationary.

Why: Contrast the moving balanced-force example: the same zero acceleration preserves whichever velocity the object already had.

It remains stationary while the forces stay balanced.

Together — We do

Follow the guided example

Together: a 3 kg trolley has a 13 N push right and 4 N resistance left. Complete $F = __ - __$, then $3a = __$, and explain each operation.

Step 1

Before: Forces act in opposite horizontal directions.

Action: Choose rightwards as positive.

After: Push = +13 N; resistance = -4 N

Why: The signs identify direction on one axis.

Step 2

Before: $F = __ - __$

Action: Include both forces and subtract their magnitudes.

After: $F = 13 - 4 = 9$ N rightwards

Why: Newton's second law uses the resultant.

Step 3

Before: $F = ma$; $F = 9$ N; $m = 3$ kg

Action: Substitute the resultant and mass.

After: $9 = 3a$

Why: Acceleration is the unknown; the same relation can be written $3a = 9$.

Step 4

Before: $3a = 9$

Action: Divide both sides by three.

After: $(3a)/3 = 9/3$; $a = 3 \text{ m s}^{-2}$ rightwards

Why: Matching factors reduce to one; $\text{N/kg} = \text{m s}^{-2}$.

$$\begin{array}{ccc} 3a & = & 9 \\ \div 3 & & \div 3 \end{array}$$

Apply the same action to both sides.

$$a = 3$$

Apply $\div 3$ to both sides

$3a$ equals 9. Apply $\div 3$ to each side. Result: a equals 3.

Step 5

Before: $a = 3 \text{ m s}^{-2}$ rightwards

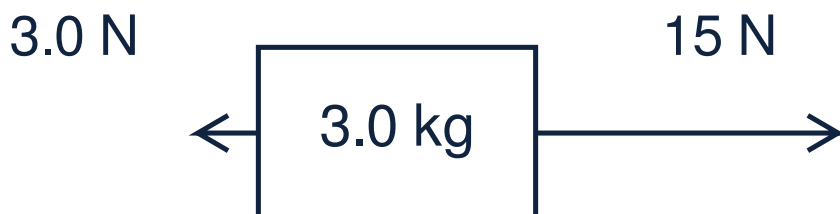
Action: Multiply back and compare the direction.

After: $ma = 3 \times 3 = 9 \text{ N} = 13 - 4$

Why: The stronger rightward force and acceleration point right.

Net force is 9 N rightwards; acceleration is 3 m s^{-2} rightwards.

Question 1



Rightwards positive.

Arrow lengths use the same force scale.

Horizontal forces on one trolley

A 3.0 kilogram trolley has 15 newtons rightwards and 3.0 newtons leftwards. Upward support balances downward weight. Only the horizontal forces are shown. Arrow lengths are proportional to force magnitude within this diagram.

Complete the method: a 3.0 kg trolley has 15 N rightwards and 3.0 N leftwards. Fill $F = 15 - \underline{\quad}$, then $a = F/\underline{\quad}$.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: $F = 15 - 3.0 = 12 \text{ N}$

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (12)/3 = 4 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 4 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 3 \times (4) = 12 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$F = 15 - 3.0 = 12 \text{ N}$ rightwards. $a = 12/3.0 = 4.0 \text{ m s}^{-2}$ rightwards. Check: $3.0 \times 4.0 = 12 \text{ N}$.

$F = 15 - 3.0 = 12 \text{ N}$ rightwards. $a = 12/3.0 = 4.0 \text{ m s}^{-2}$ rightwards.

Check: $3.0 \times 4.0 = 12 \text{ N}$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Find net force before acceleration.

Write $F = 15 - 3.0$.

The net force is 12 N. Divide it by the stated mass.

Question 2

4.0 N right + 2.0 N right

$$F = 4.0 + 2.0$$

$$a = F/2.0$$

Same-direction forces

$$4.0 \text{ N right} + 2.0 \text{ N right } F = 4.0 + 2.0 \quad a = F/2.0$$

Two forces 4.0 N and 2.0 N both act rightwards on a 2.0 kg object. Choose addition or subtraction, then find acceleration.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

$$\text{After: } F = 4.0 + 2.0 = 6.0 \text{ N}$$

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\frac{F}{m} = \frac{m \times a}{m}$$

$$\frac{F}{m} = \frac{\cancel{m} \times a}{\cancel{m}}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (6)/2 = 3 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 3 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 2 \times (3) = 6 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

Same direction: $F = 4.0 + 2.0 = 6.0 \text{ N}$ rightwards. $a = 6.0/2.0 = 3.0 \text{ m s}^{-2}$ rightwards.

Same direction: $F = 4.0 + 2.0 = 6.0 \text{ N}$ rightwards. $a = 6.0/2.0 = 3.0 \text{ m s}^{-2}$ rightwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Use directions to combine forces.

Both signed forces are positive.

Add the forces, then divide their sum by 2.0 kg.

Question 3

$$\begin{array}{rcl}
 P - 1 & = & 6 \\
 +1 & & +1 \\
 \hline
 P & = & 7
 \end{array}$$

Opposite terms sum to zero.

$$P = 7$$

Apply +1 to both sides

$P - 1$ equals 6. Apply +1 to each side. Result: P equals 7. The marked opposite terms sum to zero.

Complete $P - 1.0 = ma$ for a 3.0 kg trolley needing 2.0 m s^{-2} rightward acceleration.

Answer and working

Step 1

Before: Unknown push P ; known mass and acceleration.

Action: Find the required net force first.

After: $F = ma = 3.0 \times 2.0 = 6.0 \text{ N}$

Why: The required net force differs from the push because resistance also acts.

Step 2

Before: P rightwards; 1.0 N leftwards.

Action: Write the signed force equation.

After: $P - 1.0 = 6.0$

Why: Rightwards is positive.

Step 3

Before: $P - 1.0 = 6.0$

Action: Add 1.0 to both sides.

After: $P - 1.0 + 1.0 = 6.0 + 1.0$; $P = 7.0 \text{ N}$

Why: The opposite resistance terms sum to zero.

$$\begin{array}{rcl}
 P - 1 & = & 6 \\
 + 1 & & + 1 \\
 \hline
 P & \overset{=1}{-1} & \overset{+1}{-1} = 7 \\
 \text{Opposite terms sum to zero.} \\
 P & = & 7
 \end{array}$$

Apply +1 to both sides

$P - 1$ equals 6. Apply +1 to each side. Result: P equals 7. The marked opposite terms sum to zero.

Step 4

Before: $P = 7.0 \text{ N}$

Action: Subtract resistance and divide by mass.

After: $(7.0 - 1.0)/3.0 = 2.0 \text{ m s}^{-2}$

Why: The requested acceleration is recovered.

$ma = 3.0 \times 2.0 = 6.0 \text{ N}$. $P - 1.0 = 6.0$. Add 1.0 to both sides: $P = 7.0 \text{ N}$ rightwards. Check: $(7.0 - 1.0)/3.0 = 2.0 \text{ m s}^{-2}$.

$ma = 3.0 \times 2.0 = 6.0 \text{ N}$.

$P - 1.0 = 6.0$.

Add 1.0 to both sides: $P = 7.0 \text{ N}$ rightwards.

Check: $(7.0 - 1.0)/3.0 = 2.0 \text{ m s}^{-2}$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Find required net force first.

Calculate $ma = 3.0 \times 2.0$.

$P - 1.0 = 6.0$. Add the resistance to both sides.

Question 17

Complete the mass method for $F = 18 \text{ N}$ rightwards and $a = 6.0 \text{ m s}^{-2}$ rightwards: $18 = m \times 6.0$. Show division beneath both sides.

Answer and working

Step 1

Before: $F = 18 \text{ N}$; $a = 6 \text{ m s}^{-2}$

Action: Identify mass as the unknown.

After: $F = ma$

Why: Use matching directions for force and acceleration.

Step 2

Before: $F = ma$

Action: Divide both sides by nonzero a .

After: $F/a = ma/a$; $m = F/a$

Why: The matching a factors reduce to one.

$$\frac{F}{a} = \frac{m \times a}{a}$$

$a/a = 1$; m remains.

$$m = F/a$$

Divide both sides by a ; matching factors reduce to one

F equals m times a . Divide both sides by a . The numerator and denominator factors a reduce to one; m remains. m equals F divided by a . The divisor must be nonzero.

Step 3

Before: $m = F/a$

Action: Substitute both signed values.

After: $m = (18)/(6) = 3 \text{ kg}$

Why: Matching signs give positive mass. Force divided by acceleration leaves kilograms.

Step 4

Before: $m = 3 \text{ kg}$

Action: Multiply by the given acceleration.

After: $ma = 3 \times (6) = 18 \text{ N}$

Why: The force matches the original data.

Divide both sides by 6.0: $18/6.0 = (m \times 6.0)/6.0$. Matching 6.0 factors reduce to one, so $m = 18/6.0 = 3.0 \text{ kg}$.

Check: $3.0 \times 6.0 = 18 \text{ N}$.

Divide both sides by 6.0: $18/6.0 = (m \times 6.0)/6.0$.

Matching 6.0 factors reduce to one, so $m = 18/6.0 = 3.0 \text{ kg}$.

Check: $3.0 \times 6.0 = 18 \text{ N}$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify mass as the unknown.

Divide both sides of $18 = m \times 6.0$ by the nonzero acceleration.

The matching acceleration factors reduce to one; finish $18/6.0$ and use kilograms.

Question 18

A trolley moves right at 1.5 m s^{-1} . Forces of 4.0 N act right and left. Complete the net force, acceleration and subsequent velocity.

Answer and working

Step 1

Before: Opposing forces are both 4 N .

Action: Add their signed components.

After: $F = 4 - 4 = 0 \text{ N}$

Why: Equal opposing forces balance.

Step 2

Before: $F = 0 \text{ N}$; mass is positive.

Action: Use Newton's second law.

After: $a = F/m = 0/m = 0 \text{ m s}^{-2}$

Why: Zero acceleration means no change in velocity.

Step 3

Before: The velocity before the balanced forces is 1.5 m s^{-1} rightwards.

Action: Preserve that initial velocity.

After: Velocity remains 1.5 m s^{-1} rightwards.

Why: Acceleration changes velocity; it does not specify the initial velocity.

$F = 4.0 - 4.0 = 0 \text{ N}$. For positive mass, $a = 0/m = 0 \text{ m s}^{-2}$. Its velocity remains 1.5 m s^{-1} rightwards while those forces remain balanced.

$F = 4.0 - 4.0 = 0 \text{ N}$.

For positive mass, $a = 0/m = 0 \text{ m s}^{-2}$.

Its velocity remains 1.5 m s^{-1} rightwards while those forces remain balanced.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Distinguish velocity from a change in velocity.

Calculate $F = 4.0 - 4.0$.

Net force and acceleration are zero; preserve the velocity it already had.

With help

Apply the method: teaching example

Solve a trolley problem with less help: mass 2 kg, 11 N right and 5 N left.

Step 1

Before: Choose a direction and identify all forces.

Action: Write net force, then isolate acceleration.

After: $F = 11 - 5 = 6 \text{ N}$; $a = 6/2 = 3 \text{ m s}^{-2}$ rightwards

Why: Check $2 \times 3 = 6 \text{ N}$.

3 m s^{-2} rightwards.

Question 4



Rightwards positive.

Arrow lengths use the same force scale.

Horizontal forces on one trolley

A 2.0 kilogram trolley has 10 newtons rightwards and 16 newtons leftwards. Upward support balances downward weight. Only the horizontal forces are shown. Arrow lengths are proportional to force magnitude within this diagram.

A 2.0 kg object has 10 N rightwards and 16 N leftwards. Find acceleration.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: $F = 10 - 16 = -6.0 \text{ N}$

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (-6)/2 = -3 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = -3 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 2 \times (-3) = -6 \text{ N}$; leftwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$F = 10 - 16 = -6.0 \text{ N}$. $a = -6.0/2.0 = -3.0 \text{ m s}^{-2}$, or 3.0 m s^{-2} leftwards.

$F = 10 - 16 = -6.0 \text{ N}$. $a = -6.0/2.0 = -3.0 \text{ m s}^{-2}$, or 3.0 m s^{-2} leftwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Combine signed forces on the same object.

Choose rightwards positive: $F = 10 - 16$.

$F = -6.0 \text{ N}$; divide by 2.0 kg and interpret the sign.

Question 5

A net force of 16 N rightwards produces 4.0 m s^{-2} rightwards acceleration. Find mass.

Answer and working

Step 1

Before: $F = 16 \text{ N}$; $a = 4 \text{ m s}^{-2}$

Action: Identify mass as the unknown.

After: $F = ma$

Why: Use matching directions for force and acceleration.

Step 2

Before: $F = ma$

Action: Divide both sides by nonzero a .

After: $F/a = ma/a$; $m = F/a$

Why: The matching a factors reduce to one.

$$\frac{F}{a} = \frac{m \times a}{a}$$

$a/a = 1$; m remains.

$$m = F/a$$

Divide both sides by a ; matching factors reduce to one

F equals m times a . Divide both sides by a . The numerator and denominator factors a reduce to one; m remains. m equals F divided by a . The divisor must be nonzero.

Step 3

Before: $m = F/a$

Action: Substitute both signed values.

After: $m = (16)/(4) = 4 \text{ kg}$

Why: Matching signs give positive mass. Force divided by acceleration leaves kilograms.

Step 4

Before: $m = 4 \text{ kg}$

Action: Multiply by the given acceleration.

After: $ma = 4 \times (4) = 16 \text{ N}$

Why: The force matches the original data.

$F = ma$. Divide both sides by a : $m = F/a = 16/4.0 = 4.0 \text{ kg}$. Check: $4.0 \times 4.0 = 16 \text{ N}$.

$F = ma$.

Divide both sides by a : $m = F/a = 16/4.0 = 4.0 \text{ kg}$.

Check: $4.0 \times 4.0 = 16 \text{ N}$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown as mass.

Divide $F = ma$ by nonzero acceleration on both sides.

$m = 16/4.0$. Calculate and use kilograms.

Question 6

A 5.0 kg trolley needs 2.0 m s^{-2} rightwards against 4.0 N resistance. Find push.

Answer and working

Step 1

Before: Unknown push P; known mass and acceleration.

Action: Find the required net force first.

After: $F = ma = 5.0 \times 2.0 = 10.0 \text{ N}$

Why: The required net force differs from the push because resistance also acts.

Step 2

Before: P rightwards; 4.0 N leftwards.

Action: Write the signed force equation.

After: $P - 4.0 = 10.0$

Why: Rightwards is positive.

Step 3

Before: $P - 4.0 = 10.0$

Action: Add 4.0 to both sides.

After: $P - 4.0 + 4.0 = 10.0 + 4.0$; $P = 14.0 \text{ N}$

Why: The opposite resistance terms sum to zero.

$$\begin{array}{rcl} P - 4 & = & 10 \\ +4 & & +4 \\ \hline P & = & 14 \end{array}$$

Opposite terms sum to zero.

$P = 14$

Apply +4 to both sides

$P - 4$ equals 10. Apply +4 to each side. Result: P equals 14. The marked opposite terms sum to zero.

Step 4

Before: $P = 14.0 \text{ N}$

Action: Subtract resistance and divide by mass.

After: $(14.0 - 4.0)/5.0 = 2.0 \text{ m s}^{-2}$

Why: The requested acceleration is recovered.

$F = 5.0 \times 2.0 = 10 \text{ N}$. $P - 4.0 = 10$. Add 4.0 to both sides: $P = 14 \text{ N}$ rightwards. Check: $(14 - 4.0)/5.0 = 2.0 \text{ m s}^{-2}$.

$$F = 5.0 \times 2.0 = 10 \text{ N.}$$
$$P - 4.0 = 10.$$

Add 4.0 to both sides: $P = 14 \text{ N}$ rightwards.

Check: $(14 - 4.0)/5.0 = 2.0 \text{ m s}^{-2}$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Net force and pushing force differ.

Find $F = ma = 5.0 \times 2.0$.

$P - 4.0 = 10$. Add 4.0 to both sides.

Question 7

Solve $4z + 3 = 19$ and check.

Answer and working

Step 1

Before: $4z + 3 = 19$

Action: Subtract three from both sides.

After: $4z + 3 - 3 = 19 - 3$; $4z = 16$

Why: The opposite terms sum to zero.

$$\begin{array}{rclcl}
 4z + 3 & = & 19 \\
 -3 & & -3 \\
 \hline
 4z & \quad \quad \quad \cancel{+3} & \quad \quad \quad \cancel{-3} & = & 16
 \end{array}$$

Opposite terms sum to zero.

$$4z = 16$$

Apply -3 to both sides

$4z + 3$ equals 19. Apply -3 to each side. Result: $4z$ equals 16. The marked opposite terms sum to zero.

Step 2

Before: $4z = 16$

Action: Divide both sides by four.

After: $4z/4 = 16/4$; $z = 4$

Why: The matching factor four reduces to one.

$$\frac{4z}{4} = \frac{16}{4}$$

Apply the same action to both sides.

$$z = 4$$

Apply /4 to both sides

$4z$ equals 16. Apply /4 to each side. Result: z equals 4.

Step 3

Before: $z = 4$

Action: Substitute into the original equation.

After: $4 \times 4 + 3 = 16 + 3 = 19$

Why: The result satisfies the original equality.

Subtract 3 from both sides: $4z + 3 - 3 = 19 - 3$; $4z = 16$. Divide both sides by 4: $z = 4$. Check: $4 \times 4 + 3 = 19$.

Subtract 3 from both sides: $4z + 3 - 3 = 19 - 3$; $4z = 16$.

Divide both sides by 4: $z = 4$.

Check: $4 \times 4 + 3 = 19$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Use the same operation on both sides.

Subtract three from both sides.

$4z = 16$. Divide both sides by four, then check in the original equation.

On my own

Question 8

A 2.0 kg object has 14 N rightwards and 6.0 N leftwards. Find net force and acceleration.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: $F = 14 - 6.0 = 8.0 \text{ N}$

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (8)/2 = 4 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 4 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 2 \times (4) = 8 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$F = 14 - 6.0 = 8.0 \text{ N}$ rightwards. $a = 8.0/2.0 = 4.0 \text{ m s}^{-2}$ rightwards.

$F = 14 - 6.0 = 8.0 \text{ N}$ rightwards. $a = 8.0/2.0 = 4.0 \text{ m s}^{-2}$ rightwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and the forces on one object.

Choose rightwards positive and write the signed net force where needed.

Choose $F = ma$, $a = F/m$ or $m = F/a$; substitute the given values and interpret direction.

Question 9

A 3.0 kg object has 9.0 N rightwards and 15 N leftwards. Find acceleration.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: $F = 9.0 - 15 = -6.0 \text{ N}$

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (-6)/3 = -2 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = -2 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 3 \times (-2) = -6 \text{ N}$; leftwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$F = 9.0 - 15 = -6.0 \text{ N}$. $a = -6.0/3.0 = -2.0 \text{ m s}^{-2}$; 2.0 m s^{-2} leftwards.

$F = 9.0 - 15 = -6.0 \text{ N}$. $a = -6.0/3.0 = -2.0 \text{ m s}^{-2}$; 2.0 m s^{-2} leftwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and the forces on one object.

Choose rightwards positive and write the signed net force where needed.

Choose $F = ma$, $a = F/m$ or $m = F/a$; substitute the given values and interpret direction.

Question 10

Forces 6.0 N and 4.0 N both act rightwards on a 5.0 kg object. Find acceleration.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: $F = 6.0 + 4.0 = 10 \text{ N}$

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\frac{F}{m} = \frac{m \times a}{m}$$

$$\frac{F}{m} = \frac{\cancel{m} \times a}{\cancel{m}}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (10)/5 = 2 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 2 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 5 \times (2) = 10 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$F = 6.0 + 4.0 = 10 \text{ N}$ rightwards. $a = 10/5.0 = 2.0 \text{ m s}^{-2}$ rightwards.

$F = 6.0 + 4.0 = 10 \text{ N}$ rightwards. $a = 10/5.0 = 2.0 \text{ m s}^{-2}$ rightwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and the forces on one object.

Choose rightwards positive and write the signed net force where needed.

Choose $F = ma$, $a = F/m$ or $m = F/a$; substitute the given values and interpret direction.

Question 11

A 4.0 kg object accelerates at 1.5 m s^{-2} rightwards. Find net force.

Answer and working

Step 1

Before: $m = 4 \text{ kg}$; $a = 1.5 \text{ m s}^{-2}$

Action: Find net force directly.

After: $F = ma$

Why: Mass and acceleration are both supplied.

Step 2

Before: $F = ma$

Action: Substitute and multiply.

After: $F = 4 \times (1.5) = 6 \text{ N}$

Why: kg m s^{-2} is the newton unit; force follows the acceleration direction.

Step 3

Before: $F = 6 \text{ N}$

Action: Divide by the original mass.

After: $F/m = (6)/4 = 1.5 \text{ m s}^{-2}$

Why: The original acceleration is recovered.

$F = ma = 4.0 \times 1.5 = 6.0 \text{ N}$ rightwards.

$F = ma = 4.0 \times 1.5 = 6.0 \text{ N}$ rightwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and the forces on one object.

Choose rightwards positive and write the signed net force where needed.

Choose $F = ma$, $a = F/m$ or $m = F/a$; substitute the given values and interpret direction.

Question 12

Net force 12 N rightwards produces acceleration 3.0 m s^{-2} rightwards. Find mass.

Answer and working

Step 1

Before: $F = 12 \text{ N}$; $a = 3 \text{ m s}^{-2}$

Action: Identify mass as the unknown.

After: $F = ma$

Why: Use matching directions for force and acceleration.

Step 2

Before: $F = ma$

Action: Divide both sides by nonzero a .

After: $F/a = ma/a$; $m = F/a$

Why: The matching a factors reduce to one.

$$\frac{F}{a} = \frac{m \times a}{a}$$

$a/a = 1$; m remains.

$$m = F/a$$

Divide both sides by a ; matching factors reduce to one

F equals m times a . Divide both sides by a . The numerator and denominator factors a reduce to one; m remains. m equals F divided by a . The divisor must be nonzero.

Step 3

Before: $m = F/a$

Action: Substitute both signed values.

After: $m = (12)/(3) = 4 \text{ kg}$

Why: Matching signs give positive mass. Force divided by acceleration leaves kilograms.

Step 4

Before: $m = 4 \text{ kg}$

Action: Multiply by the given acceleration.

After: $ma = 4 \times (3) = 12 \text{ N}$

Why: The force matches the original data.

$F = ma$. Divide both sides by a : $m = F/a = 12/3.0 = 4.0 \text{ kg}$.

$F = ma$.

Divide both sides by a : $m = F/a = 12/3.0 = 4.0 \text{ kg}$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and the forces on one object.

Choose rightwards positive and write the signed net force where needed.

Choose $F = ma$, $a = F/m$ or $m = F/a$; substitute the given values and interpret direction.

Question 13

A 3.0 kg trolley needs 2.0 m s^{-2} rightwards acceleration against 4.0 N resistance. Find push.

Answer and working

Step 1

Before: Unknown push P; known mass and acceleration.

Action: Find the required net force first.

After: $F = ma = 3.0 \times 2.0 = 6.0 \text{ N}$

Why: The required net force differs from the push because resistance also acts.

Step 2

Before: P rightwards; 4.0 N leftwards.

Action: Write the signed force equation.

After: $P - 4.0 = 6.0$

Why: Rightwards is positive.

Why: The opposite resistance terms sum to zero.

Opposite terms sum to zero.

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Page 63 of 117

Check: $(10 - 4.0)/3.0 = 2.0 \text{ m s}^{-2}$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and the forces on one object.

Choose rightwards positive and write the signed net force where needed.

Choose $F = ma$, $a = F/m$ or $m = F/a$; substitute the given values and interpret direction.

Question 14

A trolley moves right at 2.0 m s^{-1} . Opposing forces are each 6.0 N . Describe subsequent motion.

Answer and working

Step 1

Before: Opposing forces are both 6 N .

Action: Add their signed components.

After: $F = 6 - 6 = 0 \text{ N}$

Why: Equal opposing forces balance.

Step 2

Before: $F = 0 \text{ N}$; mass is positive.

Action: Use Newton's second law.

After: $a = F/m = 0/m = 0 \text{ m s}^{-2}$

Why: Zero acceleration means no change in velocity.

Step 3

Before: The velocity before the balanced forces is 2 m s^{-1} rightwards.

Action: Preserve that initial velocity.

After: Velocity remains 2 m s^{-1} rightwards.

Why: Acceleration changes velocity; it does not specify the initial velocity.

$F = 6.0 - 6.0 = 0 \text{ N}$, so $a = 0$. It continues at 2.0 m s^{-1} rightwards while forces remain unchanged.

$F = 6.0 - 6.0 = 0 \text{ N}$, so $a = 0$.

It continues at 2.0 m s^{-1} rightwards while forces remain unchanged.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and the forces on one object.

Choose rightwards positive and write the signed net force where needed.

Choose $F = ma$, $a = F/m$ or $m = F/a$; substitute the given values and interpret direction.

Question 15

An 8.0 N net force acts on a 2.0 kg cart, then on a 4.0 kg cart. Compare accelerations.

Answer and working

Step 1

Before: Given net force 8 N; mass 2 kg.

Action: Identify acceleration as the unknown.

After: Use $F = ma$.

Why: Net force is already supplied; do not add it as an extra force.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (8)/2 = 4 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 4 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 2 \times (4) = 8 \text{ N}$; in the direction of the net force

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

Step 5

Before: Given net force 8 N; mass 4 kg.

Action: Identify acceleration as the unknown.

After: Use $F = ma$.

Why: Net force is already supplied; do not add it as an extra force.

Step 6

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\frac{F}{m} = \frac{m \times a}{m}$$

$$\frac{F}{m} = \frac{\cancel{m} \times a}{\cancel{m}}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 7

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (8)/4 = 2 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 8

Before: $a = 2 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 4 \times (2) = 8 \text{ N}$; in the direction of the net force

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

Step 9

Before: Accelerations 4 and 2 m s^{-2} .

Action: Compare the mass change with the acceleration change.

After: Doubling mass halves acceleration at unchanged net force.

Why: The force was held constant.

$a = 8.0/2.0 = 4.0 \text{ m s}^{-2}$; $a = 8.0/4.0 = 2.0 \text{ m s}^{-2}$. Both follow the force direction. Doubling mass halves acceleration at unchanged net force.

$a = 8.0/2.0 = 4.0 \text{ m s}^{-2}$; $a = 8.0/4.0 = 2.0 \text{ m s}^{-2}$.

Both follow the force direction.

Doubling mass halves acceleration at unchanged net force.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and the forces on one object.

Choose rightwards positive and write the signed net force where needed.

Choose $F = ma$, $a = F/m$ or $m = F/a$; substitute the given values and interpret direction.

Question 16

Which conclusion follows from zero net force?

Circle your answer:

- A. Velocity remains unchanged.
- B. The object must be stationary.
- C. No forces can act on the object.

Answer and working

Step 1

Before: The supplied net force is zero.

Action: Use the given resultant directly.

After: $F = 0 \text{ N}$

Why: Individual forces may be absent or may cancel; their magnitudes were not supplied.

Step 2

Before: $F = 0 \text{ N}$; mass is positive.

Action: Use Newton's second law.

After: $a = F/m = 0/m = 0 \text{ m s}^{-2}$

Why: Zero acceleration means no change in velocity.

Step 3

Before: The velocity before the balanced forces is not specified.

Action: Preserve that initial velocity.

After: Velocity remains unchanged; it need not be zero.

Why: Acceleration changes velocity; it does not specify the initial velocity.

$F = ma$ with positive mass gives $a = 0$; velocity stays unchanged.

$F = ma$ with positive mass gives $a = 0$; velocity stays unchanged.

Hints to offer

Identify the relationship being tested.

Use the definitions before comparing the options.

Reject options that contradict the relationship; select the remaining option.

Come back

Question 19

A 2 kg object has net force 8 N rightwards. Find acceleration.

Answer and working

Step 1

Before: Given net force 8 N; mass 2 kg.

Action: Identify acceleration as the unknown.

After: Use $F = ma$.

Why: Net force is already supplied; do not add it as an extra force.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (8)/2 = 4 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 4 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 2 \times (4) = 8 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

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

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

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 20

A 3 kg object has net force 9 N leftwards. Find acceleration.

Answer and working

Step 1

Before: Given net force -9 N ; mass 3 kg.

Action: Identify acceleration as the unknown.

After: Use $F = ma$.

Why: Net force is already supplied; do not add it as an extra force.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (-9)/3 = -3 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = -3 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 3 \times (-3) = -9 \text{ N}$; leftwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

With rightwards positive: $a = -9/3 = -3 \text{ m s}^{-2}$, or 3 m s^{-2} leftwards.

With rightwards positive: $a = -9/3 = -3 \text{ m s}^{-2}$, or 3 m s^{-2} leftwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 21

A 5 kg object has net force 20 N rightwards. Find acceleration.

Answer and working

Step 1

Before: Given net force 20 N; mass 5 kg.

Action: Identify acceleration as the unknown.

After: Use $F = ma$.

Why: Net force is already supplied; do not add it as an extra force.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (20)/5 = 4 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 4 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 5 \times (4) = 20 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$a = 20/5 = 4 \text{ m s}^{-2}$ rightwards.

$a = 20/5 = 4 \text{ m s}^{-2}$ rightwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 22

A 4 kg object has net force 6 N rightwards. Find acceleration.

Answer and working

Step 1

Before: Given net force 6 N; mass 4 kg.

Action: Identify acceleration as the unknown.

After: Use $F = ma$.

Why: Net force is already supplied; do not add it as an extra force.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (6)/4 = 1.5 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 1.5 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 4 \times (1.5) = 6 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$a = 6/4 = 1.5 \text{ m s}^{-2}$ rightwards. Acceleration need not be an integer.

$a = 6/4 = 1.5 \text{ m s}^{-2}$ rightwards.

Acceleration need not be an integer.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 23

A 3 kg object has zero net force. Find acceleration. Can its speed be determined?

Answer and working

Step 1

Before: Given net force 0 N; mass 3 kg.

Action: Identify acceleration as the unknown.

After: Use $F = ma$.

Why: Net force is already supplied; do not add it as an extra force.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (0)/3 = 0 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 0 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 3 \times (0) = 0 \text{ N}$; no acceleration

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$a = 0/3 = 0 \text{ m s}^{-2}$. Initial velocity is needed to determine speed; it may already be moving.

$a = 0/3 = 0 \text{ m s}^{-2}$.

Initial velocity is needed to determine speed; it may already be moving.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 24

A 4 kg object has 18 N rightwards and 6 N leftwards. Find net force and acceleration.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: $F = 18 - 6 = 12 \text{ N}$

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (12)/4 = 3 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 3 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 4 \times (3) = 12 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$F = 18 - 6 = 12 \text{ N}$ rightwards; $a = 12/4 = 3 \text{ m s}^{-2}$ rightwards.

$F = 18 - 6 = 12 \text{ N}$ rightwards; $a = 12/4 = 3 \text{ m s}^{-2}$ rightwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 25

Forces 6 N and 4 N both act rightwards on a 2 kg object. Find acceleration.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: $F = 6 + 4 = 10 \text{ N}$

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (10)/2 = 5 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 5 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 2 \times (5) = 10 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$F = 6 + 4 = 10 \text{ N}$ rightwards; $a = 10/2 = 5 \text{ m s}^{-2}$ rightwards.

$F = 6 + 4 = 10 \text{ N}$ rightwards; $a = 10/2 = 5 \text{ m s}^{-2}$ rightwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 26

A 3 kg object has 4 N rightwards and 10 N leftwards. Find acceleration.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: $F = 4 - 10 = -6 \text{ N}$

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (-6)/3 = -2 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = -2 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 3 \times (-2) = -6 \text{ N}$; leftwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$F = 4 - 10 = -6 \text{ N}$; $a = -6/3 = -2 \text{ m s}^{-2}$, or 2 m s^{-2} leftwards.

$F = 4 - 10 = -6 \text{ N}$; $a = -6/3 = -2 \text{ m s}^{-2}$, or 2 m s^{-2} leftwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 27

A 5 kg object has 8 N rightwards, 5 N rightwards and 3 N leftwards. Find acceleration.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: $F = 8 + 5 - 3 = 10 \text{ N}$

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (10)/5 = 2 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 2 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 5 \times (2) = 10 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$F = 8 + 5 - 3 = 10 \text{ N}$ rightwards; $a = 10/5 = 2 \text{ m s}^{-2}$ rightwards.

$F = 8 + 5 - 3 = 10 \text{ N}$ rightwards; $a = 10/5 = 2 \text{ m s}^{-2}$ rightwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 28

A 3 kg object accelerates at 2 m s^{-2} leftwards. Find net force.

Answer and working

Step 1

Before: $m = 3 \text{ kg}$; $a = -2 \text{ m s}^{-2}$

Action: Find net force directly.

After: $F = ma$

Why: Mass and acceleration are both supplied.

Step 2

Before: $F = ma$

Action: Substitute and multiply.

After: $F = 3 \times (-2) = -6 \text{ N}$

Why: kg m s^{-2} is the newton unit; force follows the acceleration direction.

Step 3

Before: $F = -6 \text{ N}$

Action: Divide by the original mass.

After: $F/m = (-6)/3 = -2 \text{ m s}^{-2}$

Why: The original acceleration is recovered.

$F = ma = 3 \times (-2) = -6 \text{ N}$, or 6 N leftwards.

$F = ma = 3 \times (-2) = -6 \text{ N}$, or 6 N leftwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 29

Net force 15 N rightwards gives acceleration 3 m s^{-2} rightwards. Find mass.

Answer and working

Step 1

Before: $F = 15 \text{ N}$; $a = 3 \text{ m s}^{-2}$

Action: Identify mass as the unknown.

After: $F = ma$

Why: Use matching directions for force and acceleration.

Step 2

Before: $F = ma$

Action: Divide both sides by nonzero a .

After: $F/a = ma/a$; $m = F/a$

Why: The matching a factors reduce to one.

$$\frac{F}{a} = \frac{m \times a}{a}$$

$a/a = 1$; m remains.

$$m = F/a$$

Divide both sides by a ; matching factors reduce to one

F equals m times a . Divide both sides by a . The numerator and denominator factors a reduce to one; m remains. m equals F divided by a . The divisor must be nonzero.

Step 3

Before: $m = F/a$

Action: Substitute both signed values.

After: $m = (15)/(3) = 5 \text{ kg}$

Why: Matching signs give positive mass. Force divided by acceleration leaves kilograms.

Step 4

Before: $m = 5 \text{ kg}$

Action: Multiply by the given acceleration.

After: $ma = 5 \times (3) = 15 \text{ N}$

Why: The force matches the original data.

Divide $F = ma$ by a : $m = F/a = 15/3 = 5 \text{ kg}$. Check: $5 \times 3 = 15 \text{ N}$.

Divide $F = ma$ by a : $m = F/a = 15/3 = 5 \text{ kg}$.

Check: $5 \times 3 = 15 \text{ N}$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 30

A 2 kg object has 10 N rightwards and 4 N leftwards. A learner calculates $a = 10/2$. Repair the method.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: $F = 10 - 4 = 6 \text{ N}$; the lone rightward force is not the net force.

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (6)/2 = 3 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 3 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 2 \times (3) = 6 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

They used one force. $F = 10 - 4 = 6 \text{ N}$ rightwards; $a = 6/2 = 3 \text{ m s}^{-2}$ rightwards.

They used one force.

$F = 10 - 4 = 6 \text{ N}$ rightwards; $a = 6/2 = 3 \text{ m s}^{-2}$ rightwards.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 31

A 10 kg shopping trolley moves east. Push is 18 N east and resistance 8 N west. Find acceleration.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: $F = 18 - 8 = 10 \text{ N}$ eastwards

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (10)/10 = 1 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 1 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 10 \times (1) = 10 \text{ N}$; eastwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

East positive: $F = 18 - 8 = 10 \text{ N east}$; $a = 10/10 = 1 \text{ m s}^{-2} \text{ east}$.

East positive: $F = 18 - 8 = 10 \text{ N east}$; $a = 10/10 = 1 \text{ m s}^{-2} \text{ east}$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 32

A 0.5 kg model train has driving force 1.5 N east and resistance 0.5 N west. Find acceleration.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: $F = 1.5 - 0.5 = 1.0 \text{ N eastwards}$

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (1)/0.5 = 2 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 2 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 0.5 \times (2) = 1 \text{ N}$; eastwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$F = 1.5 - 0.5 = 1.0 \text{ N east}$; $a = 1.0/0.5 = 2 \text{ m s}^{-2} \text{ east}$.

$F = 1.5 - 0.5 = 1.0 \text{ N east}$; $a = 1.0/0.5 = 2 \text{ m s}^{-2} \text{ east}$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 33

A 20 kg crate moves right against 4 N resistance. Find the push for 0.5 m s^{-2} rightward acceleration.

Answer and working

Step 1

Before: Unknown push P; known mass and acceleration.

Action: Find the required net force first.

After: $F = ma = 20.0 \times 0.5 = 10.0 \text{ N}$

Why: The required net force differs from the push because resistance also acts.

Step 2

Before: P rightwards; 4.0 N leftwards.

Action: Write the signed force equation.

After: $P - 4.0 = 10.0$

Why: Rightwards is positive.

Step 3

Before: $P - 4.0 = 10.0$

Action: Add 4.0 to both sides.

After: $P - 4.0 + 4.0 = 10.0 + 4.0$; $P = 14.0 \text{ N}$

Why: The opposite resistance terms sum to zero.

$$\begin{array}{rcl}
 P - 4 & = & 10 \\
 +4 & & +4 \\
 \hline
 P & \overset{=}{\cancel{-4}} \quad \overset{+}{\cancel{4}} & = 14
 \end{array}$$

Opposite terms sum to zero.

$$P = 14$$

Apply +4 to both sides

$P - 4$ equals 10. Apply +4 to each side. Result: P equals 14. The marked opposite terms sum to zero.

Step 4

Before: $P = 14.0 \text{ N}$

Action: Subtract resistance and divide by mass.

After: $(14.0 - 4.0)/20.0 = 0.5 \text{ m s}^{-2}$

Why: The requested acceleration is recovered.

Required $F = 20 \times 0.5 = 10 \text{ N}$ rightwards. $P - 4 = 10$. Add 4 to both sides: $P = 14 \text{ N}$ rightwards. Check: $(14 - 4)/20 = 0.5 \text{ m s}^{-2}$.

Required $F = 20 \times 0.5 = 10 \text{ N}$ rightwards.

$P - 4 = 10$.

Add 4 to both sides: $P = 14 \text{ N}$ rightwards.

Check: $(14 - 4)/20 = 0.5 \text{ m s}^{-2}$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 34

Two helpers push a 4 kg trolley east with 6 N and 9 N. Resistance is 3 N west. Find acceleration.

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: $F = 6 + 9 - 3 = 12 \text{ N eastwards}$

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (12)/4 = 3 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 3 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 4 \times (3) = 12 \text{ N}$; eastwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

$F = 6 + 9 - 3 = 12 \text{ N east}$; $a = 12/4 = 3 \text{ m s}^{-2} \text{ east}$.

$F = 6 + 9 - 3 = 12 \text{ N east}$; $a = 12/4 = 3 \text{ m s}^{-2} \text{ east}$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 35

A delivery robot accelerates at 2 m s^{-2} leftwards under net force 24 N leftwards. Find mass.

Answer and working

Step 1

Before: $F = -24 \text{ N}$; $a = -2 \text{ m s}^{-2}$

Action: Identify mass as the unknown.

After: $F = ma$

Why: Use matching directions for force and acceleration.

Step 2

Before: $F = ma$

Action: Divide both sides by nonzero a .

After: $F/a = ma/a$; $m = F/a$

Why: The matching a factors reduce to one.

$$\begin{array}{ccc} F & = & m \times a \\ / a & & / a \\ \hline \frac{F}{a} & = & \frac{m \times \cancel{a}}{\cancel{a}} \end{array}$$

$a/a = 1$; m remains.

$$m = F/a$$

Divide both sides by a ; matching factors reduce to one

F equals m times a . Divide both sides by a . The numerator and denominator factors a reduce to one; m remains. m equals F divided by a . The divisor must be nonzero.

Step 3

Before: $m = F/a$

Action: Substitute both signed values.

After: $m = (-24)/(-2) = 12 \text{ kg}$

Why: Matching signs give positive mass. Force divided by acceleration leaves kilograms.

Step 4

Before: $m = 12 \text{ kg}$

Action: Multiply by the given acceleration.

After: $ma = 12 \times (-2) = -24 \text{ N}$

Why: The force matches the original data.

Matching signed directions: $m = F/a = (-24)/(-2) = 12 \text{ kg}$. Check magnitude: $12 \times 2 = 24 \text{ N}$.

Matching signed directions: $m = F/a = (-24)/(-2) = 12 \text{ kg}$.

Check magnitude: $12 \times 2 = 24 \text{ N}$.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 36

A 6 kg trolley moves right at 2 m s^{-1} with forces 13 N right and 13 N left. Describe motion.

Answer and working

Step 1

Before: Opposing forces are both 13 N.

Action: Add their signed components.

After: $F = 13 - 13 = 0 \text{ N}$

Why: Equal opposing forces balance.

Step 2

Before: $F = 0 \text{ N}$; mass is positive.

Action: Use Newton's second law.

After: $a = F/m = 0/m = 0 \text{ m s}^{-2}$

Why: Zero acceleration means no change in velocity.

Step 3

Before: The velocity before the balanced forces is 2 m s^{-1} rightwards.

Action: Preserve that initial velocity.

After: Velocity remains 2 m s^{-1} rightwards.

Why: Acceleration changes velocity; it does not specify the initial velocity.

$F = 13 - 13 = 0 \text{ N}$; $a = 0/6 = 0$. It continues at 2 m s^{-1} rightwards while forces remain balanced.

$F = 13 - 13 = 0 \text{ N}$; $a = 0/6 = 0$.

It continues at 2 m s^{-1} rightwards while forces remain balanced.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 37

Net force 12 N rightwards acts on carts of 3 kg and 6 kg . Calculate and compare accelerations.

Answer and working

Step 1

Before: Given net force 12 N ; mass 3 kg .

Action: Identify acceleration as the unknown.

After: Use $F = ma$.

Why: Net force is already supplied; do not add it as an extra force.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\frac{F}{m} = \frac{m \times a}{m}$$

$$\frac{F}{m} = \frac{\cancel{m} \times a}{\cancel{m}}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (12)/3 = 4 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 4 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 3 \times (4) = 12 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

Step 5

Before: Given net force 12 N; mass 6 kg.

Action: Identify acceleration as the unknown.

After: Use $F = ma$.

Why: Net force is already supplied; do not add it as an extra force.

Step 6

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 7

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (12)/6 = 2 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 8

Before: $a = 2 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 6 \times (2) = 12 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

Step 9

Before: Masses 3 and 6 kg; accelerations 4 and 2 m s^{-2} .

Action: Compare both ratios.

After: Mass doubled; acceleration halved.

Why: The same net force acted in both cases.

$a = 12/3 = 4 \text{ m s}^{-2}$ and $a = 12/6 = 2 \text{ m s}^{-2}$, both rightwards. Twice the mass gives half the acceleration at unchanged net force.

$a = 12/3 = 4 \text{ m s}^{-2}$ and $a = 12/6 = 2 \text{ m s}^{-2}$, both rightwards.

Twice the mass gives half the acceleration at unchanged net force.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Question 38

Cart A: mass 3 kg, forces 18 N right and 6 N left. Cart B: mass 3 kg, forces 15 N right and 3 N left. Does A accelerate more?

Answer and working

Step 1

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: Cart A: $F = 18 - 6 = 12 \text{ N}$

Why: Opposing force contributions have opposite signs.

Step 2

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\begin{array}{ccc} F & = & m \times a \\ / m & & / m \\ \hline \frac{F}{m} & = & \frac{\cancel{m} \times a}{\cancel{m}} \end{array}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 3

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (12)/3 = 4 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 4

Before: $a = 4 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 3 \times (4) = 12 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

Step 5

Before: Rightwards or eastwards is positive.

Action: Combine every signed force on the object.

After: Cart B: $F = 15 - 3 = 12 \text{ N}$

Why: Opposing force contributions have opposite signs.

Step 6

Before: $F = ma$

Action: Divide both sides by m .

After: $F/m = ma/m$; $a = F/m$

Why: The factor m/m reduces to one.

$$\frac{F}{m} = \frac{m \times a}{m}$$

$$\frac{F}{m} = \frac{\cancel{m} \times a}{\cancel{m}}$$

$m/m = 1$; a remains.

$$a = F/m$$

Divide both sides by m ; matching factors reduce to one

F equals m times a . Divide both sides by m . The numerator and denominator factors m reduce to one; a remains. a equals F divided by m . The divisor must be nonzero.

Step 7

Before: $a = F/m$

Action: Substitute the signed net force and positive mass.

After: $a = (12)/3 = 4 \text{ m s}^{-2}$

Why: N/kg gives $\text{kg m s}^{-2}/\text{kg}$; the matching kg factors reduce to one.

Step 8

Before: $a = 4 \text{ m s}^{-2}$

Action: Check force and direction.

After: $ma = 3 \times (4) = 12 \text{ N}$; rightwards

Why: The signed acceleration follows the net force; zero acceleration preserves the initial velocity.

Step 9

Before: Both net forces 12 N; both masses 3 kg.

Action: Compare their calculated accelerations.

After: Both accelerate at 4 m s^{-2} rightwards.

Why: Different individual forces can produce the same net force.

A: $F = 18 - 6 = 12 \text{ N}$. B: $F = 15 - 3 = 12 \text{ N}$. Both: $a = 12/3 = 4 \text{ m s}^{-2}$ rightwards. Applied force alone is insufficient; their net forces and masses match.

A: $F = 18 - 6 = 12 \text{ N}$.

B: $F = 15 - 3 = 12 \text{ N}$.

Both: $a = 12/3 = 4 \text{ m s}^{-2}$ rightwards.

Applied force alone is insufficient; their net forces and masses match.

What to look for

- Uses the stated physical or chemical relationship.
- Shows the relevant working and reasoning.
- Checks the result against the original conditions.

Hints to offer

Identify the unknown and use forces on the same object.

Write the signed net force or the required net force ma .

Isolate the unknown with equal operations; substitute values, then check units and direction.

Teaching notes

Focused coverage of PH11-9 (2017), not the whole Dynamics module. Starting level uses a single horizontal constant-mass object. Inclines, connected bodies and momentum are excluded. The cart-hanger Studio uses a larger system: do not treat hanger weight as the cart-only force or omit the hanger from moving mass. Students may use either signed components or clearly labelled magnitudes and directions. Preserve the existing check and tutor-confirmation logic. Both senior presentations use mature notation; tutor editions add adjacent guidance. No pupil performance guarantee is made.

Come back — fresh retrieval

Retrieval 1

A 4 kg object has 20 N right and 8 N left. Find acceleration.

$$F = 20 - 8 = 12 \text{ N right}; a = 12/4 = 3 \text{ m s}^{-2} \text{ right.}$$

Retrieval 2

Net force 10 N produces acceleration 2 m s^{-2} in the same direction. Find mass.

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

Retrieval 3

A 2 kg trolley needs 3 m s^{-2} rightwards against 2 N resistance. Find push.

$$F = 2 \times 3 = 6 \text{ N}; P - 2 = 6, \text{ so } P = 8 \text{ N rightwards.}$$

Retrieval 4

An object moves left while accelerating right. Explain its immediate speed change and what balanced forces would mean.

Its speed decreases initially because acceleration opposes velocity. With balanced forces acceleration is zero and its existing velocity remains unchanged.

Apply your understanding

Predict the change in acceleration when mass doubles while net force doubles. Justify.

Original: $a = F/m$

New: $a = (2F)/(2m)$

Matching factors reduce: a unchanged

Compare both changes

Original: $a = F/m$ New: $a = (2F)/(2m)$ Matching factors reduce: a unchanged

Answer and working

Initially $a = F/m$. Afterward $a' = (2F)/(2m) = F/m = a$; matching factors two reduce to one. Both quantities changed, so examining force alone would be incomplete.

Check common errors

Use the push alone in $F = ma$.

Draw all horizontal forces and calculate their signed sum first.

Negative acceleration always means slowing down.

Compare acceleration direction with the current velocity direction.

Balanced forces mean zero velocity.

Zero net force gives zero acceleration, so velocity remains unchanged.

The calculated ma is always the applied push.

Account for other forces; here $P - R = ma$.

Lesson review

- Combine forces with a stated direction convention.
- Select and rearrange $F = ma$ for the required quantity.
- Find a required push when an opposing force acts.
- Explain balanced forces and the direction of acceleration.