physicsUK
Smarter practice. Stronger understanding

SOLUTIONS

ATTEMPT | CHECK | CORRECT | IMPROVE

AQA AS Newton's Laws, Momentum and Impulse solutions

Matching solutions and teaching prompts for the class review

Specification points covered

• 3.4.1.5(a) Newton's first law and equilibrium. • 3.4.1.5(b) Newton's second law and F = ma for constant mass. • 3.4.1.5(c) Newton's third law and interaction pairs.	• 3.4.1.6(a–c) Momentum and rate of change of momentum. • 3.4.1.6(d–f) Impulse and force–time graphs. • 3.4.1.6(g–j) Conservation of momentum, collisions and explosions.

Teaching focus

Keep Newton's third-law pairs on different bodies.
Require a signed momentum or impulse equation before substituting values.

1. Thruster forces

1. State Newton's first, second and third laws of motion using AQA-appropriate wording. [3 marks]

Answer / mark points: First law: an object remains at rest or moves with constant velocity unless acted on by a resultant external force. Second law: the resultant force equals the rate of change of momentum; for constant mass F = ma. Third law: when two bodies interact, they exert forces on each other that are equal in magnitude, opposite in direction and of the same type.

Teacher prompt / common error: The second law is fundamentally F = dp/dt; F = ma requires constant mass.

2. An 850 kg service craft produces a forward thrust of 1.80 kN while a control thruster produces 250 N in the opposite direction. Calculate the craft's acceleration. [2 marks]

Answer / mark points: Resultant force = 1800 - 250 = 1550 N. a = F/m = 1550/850 = 1.82 m s^{-2} forward.

Teacher prompt / common error: Use the resultant force, not the larger thruster force alone.

3. Draw a free-body diagram for the craft in Question 2. Show only forces acting on the craft and label the forward direction. [2 marks]

Answer / mark points: Show a 1.80 kN thrust arrow forward and a 250 N control-thrust arrow backward, both acting on the craft, with the forward direction labelled. Do not add an action–reaction partner force on this diagram.

Teacher prompt / common error: A free-body diagram contains forces on one selected body only.

Continue your physics journey
Videos, practice and support for your next step
www.physicsuk.co.uk

2. The first docking

4. The main thruster pushes exhaust gas backwards. Use Newton's third law to identify the force pair and explain why the two forces do not cancel on the craft. [3 marks]

Answer / mark points: The craft pushes the exhaust gas backwards and the exhaust gas pushes the craft forwards. These forces are equal in magnitude, opposite in direction and the same interaction type, but they act on different bodies, so they do not cancel in the force sum for the craft.

Teacher prompt / common error: Third-law pairs act on different objects and are the same type of force.

5. The 850 kg craft moves at 0.650 m s^{-1} and docks with a stationary 1200 kg satellite. They move together after impact. Calculate their common velocity. [3 marks]

Answer / mark points: Conservation of momentum: 850(0.650) + 1200(0) = (850 + 1200)v. Therefore v = 0.270 m s^{-1} in the craft's original direction.

Teacher prompt / common error: Choose a positive direction and keep it throughout the momentum equation.

6. Calculate the total kinetic energy before and after the docking in Question 5. State whether kinetic energy is conserved and classify the collision. [3 marks]

Answer / mark points: Before: $\frac{1}{2}(850)(0.650^2)$ = 180 J. After: $\frac{1}{2}(2050)(0.2695^2)$ = 74.5 J. Kinetic energy decreases by about 105 J, so it is not conserved; because the bodies stick together, the collision is perfectly inelastic.

Teacher prompt / common error: Momentum can be conserved while kinetic energy decreases.

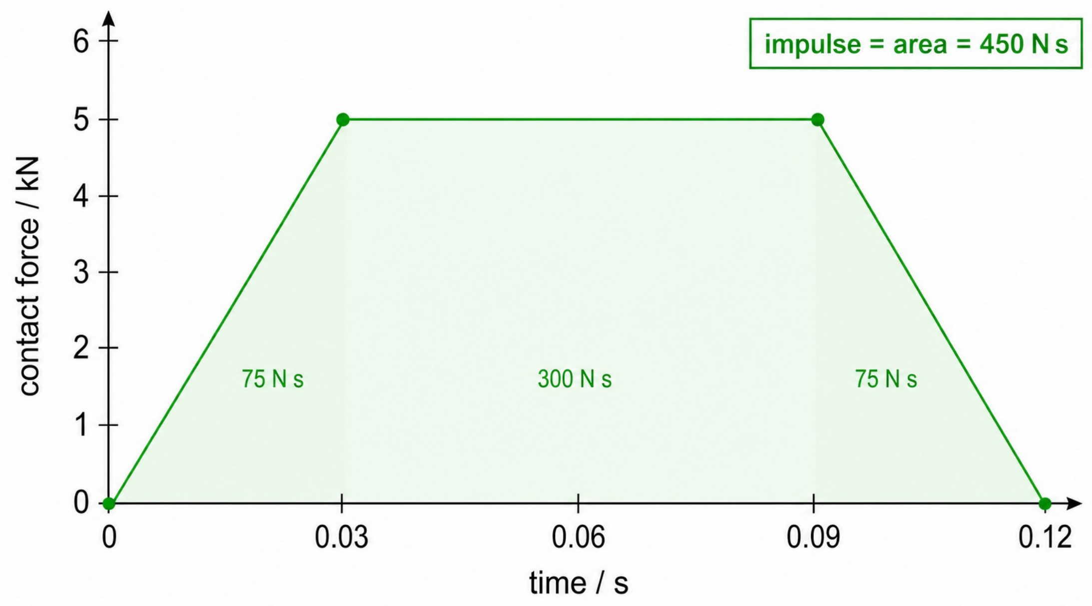
Continue your physics journey

Videos, practice and support for your next step

www.physicsuk.co.uk

3. Reading the contact record

7. The force–time graph shows a later contact force on the craft. Calculate the impulse. The force acts opposite to the craft's motion. [3 marks]



Answer / mark points: Impulse is the area under the graph: two triangles each give ½(0.030)(5000) = 75 N s and the rectangle gives (0.060)(5000) = 300 N s. Total impulse = 450 N s opposite to the motion.
Teacher prompt / common error: Convert kilonewtons to newtons before giving impulse in N s.

8. The 850 kg craft initially moves at 0.650 m s^{-1}. Use the impulse from Question 7 to calculate its velocity immediately after the contact force has acted. [3 marks]

Answer / mark points: Initial momentum = 850 × 0.650 = 552.5 kg m s^{-1}. Final momentum = 552.5 - 450 = 102.5 kg m s^{-1}. v = 102.5/850 = 0.121 m s^{-1}, still forward.
Teacher prompt / common error: The impulse is negative because it acts opposite to the motion.

Continue your physics journey
Videos, practice and support for your next step
www.physicsuk.co.uk

4. Controlling collision forces

9. Calculate the average contact force during the 0.120 s collision. [1 mark]

Answer / mark points: Average force = impulse/time = 450/0.120 = 3.75×10^3 N.
Teacher prompt / common error: Average force is total area divided by total contact time.

10. A redesigned docking buffer gives the same impulse over 0.240 s. Calculate the new average force and explain why the longer contact time reduces the risk of damage. [3 marks]

Answer / mark points: Average force = 450/0.240 = 1.88×10^3 N. For the same change in momentum, increasing the time reduces the average force and normally reduces the peak force and stress on components.
Teacher prompt / common error: The momentum change is fixed; a larger time means a smaller average force.

11. A stationary 850 kg craft ejects a 20.0 kg tool at 4.00 m s^{-1} backwards relative to the original stationary frame. Calculate the velocity of the remaining 830 kg craft. [3 marks]

Answer / mark points: Initial momentum is zero. Taking forward as positive: 20(-4.00) + 830v = 0, so v = 80.0/830 = 0.0964 m s^{-1} forward.
Teacher prompt / common error: The two final momenta must be equal in magnitude and opposite in direction.

12. A soft docking collar deforms during impact. Explain the trade-off between contact time, peak force, momentum change and kinetic-energy transfer. State which quantities are conserved for the complete isolated system. [3 marks]

Answer / mark points: Deformation increases contact time, so the same impulse or momentum change can be produced by a smaller average and peak force. Some kinetic energy is transferred to internal energy, sound and deformation, so kinetic energy need not be conserved. Total momentum is conserved for the complete isolated system; total energy is conserved although it changes form.
Teacher prompt / common error: Total energy is conserved, but kinetic energy can be transferred to other stores.

Continue your physics journey

Videos, practice and support for your next step

www.physicsuk.co.uk

5. Reconstructing the event

13. Write a structured reconstruction of the docking event using all three Newton laws, momentum conservation and impulse. Explain how the force–time record and velocity measurements can test whether the model is consistent, and identify why action–reaction forces must be assigned to different bodies. [6 marks]

Answer / mark points: Award one mark for each linked point, to six: use the resultant force on each body to predict acceleration through Newton's second law; relate a zero resultant to constant velocity using the first law; identify equal and opposite contact or thrust forces on different bodies using the third law; conserve total momentum when external impulse is negligible; obtain impulse from the area under the force–time graph and set it equal to change in momentum; compare measured initial and final momenta including direction; explain that agreement within uncertainty supports the model; do not cancel a third-law pair in a free-body diagram for one object.

Teacher prompt / common error: Keep system momentum, single-body force diagrams and third-law pairs logically separate.

Language and method check

Award independent, creditworthy physics steps; do not award extra marks for repeated statements.
Accept equivalent methods when the physical reasoning, units and final precision remain consistent.

Continue your physics journey
Videos, practice and support for your next step
www.physicsuk.co.uk