

Resultant forces and Newton's laws

AQA GCSE Physics 8463 and Combined Science Trilogy 8464 | Paper 2 | F/H core + HT extension

Worked solutions and teaching prompts | 28 core parts + 5 HT parts | 60 marks total

Specification points covered

Force, mass, weight and straight-line resultants: 8463 4.5.1.1–4.5.1.4; 8464 6.5.1.1–6.5.1.4

Newton's three laws: 8463 4.5.6.2.1–4.5.6.2.3; 8464 6.5.4.2.1–6.5.4.2.3

Acceleration from velocity change: 8463 4.5.6.1.5; 8464 6.5.4.1.5 (selected content)

Force, mass and acceleration investigation: 8463 required practical 7; 8464 required practical 19

HT only: force-vector scale drawings, inertia and inertial mass within the references above

A warehouse robot pulls loaded carts along a straight, level aisle. Engineers test its pulling force, load limits and braking, then use a model trolley to check Newton's second law. Unless stated otherwise, each test is separate and horizontal resistance includes all opposing forces.

Shared core for both routes and tiers; Questions 6–7 assess HT-only content. Accept equivalent wording and sensible follow-through. Suggested timing excludes the extension and is not classroom-tested. This original PhysicsUK resource is not an official AQA paper or mark scheme.

1 Mass, weight and the load label

The standard loaded cart has mass 40 kg. Its label gives mass, not weight.

1(a) State the difference between the cart's mass and its weight. **[2 marks]**

Answer / mark points: Mass is the amount of matter in the cart, measured in kg. [1] Weight is the gravitational force on it, measured in N. [1]

1(b) Calculate the weight of the standard loaded cart. **[1 mark]**

Answer / mark points: $W = mg = 40 \times 10 = 400 \text{ N}$. [1]

1(c) A different loaded cart has a mass of 35 000 g. Calculate its weight. **[2 marks]**

Answer / mark points: $35\,000 \text{ g} = 35 \text{ kg}$. [1] $W = 35 \times 10 = 350 \text{ N}$. [1]

1(d) A parcel on the cart weighs 80 N. Calculate the parcel's mass. **[1 mark]**

Answer / mark points: $m = W / g = 80 / 10 = 8.0 \text{ kg}$. [1]



2 Reading the forces on the cart

Figure 1 shows only the horizontal forces in three tests. Use the labelled values; arrow lengths are not a numerical scale. The loaded cart has mass 40 kg in every test.

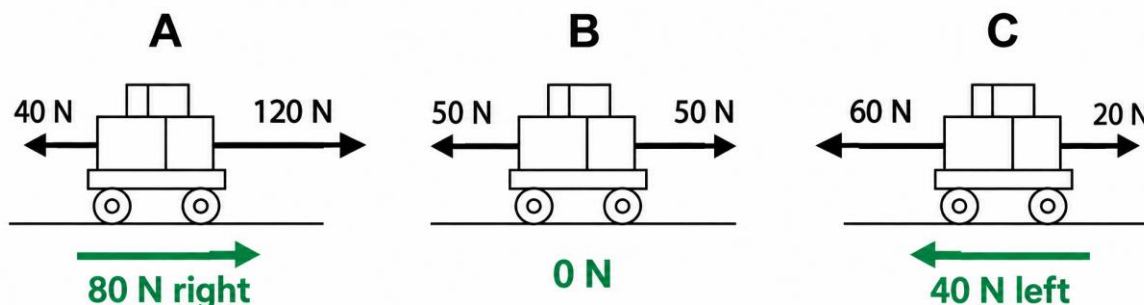


Figure 1

2(a) For test A, calculate the resultant horizontal force. Include its direction. **[1 mark]**

Answer / mark points: $120 - 40 = 80$ N to the right. [1] Magnitude and direction required.

2(b) Calculate the acceleration of the cart in test A. Include its direction. **[1 mark]**

Answer / mark points: $a = F / m = 80 / 40 = 2.0$ m s⁻² to the right. [1]

Teacher prompt: Use the 80 N resultant, not the 120 N pulling force.

2(c) For test B, calculate the resultant horizontal force. **[1 mark]**

Answer / mark points: $50 - 50 = 0$ N. [1]

2(d) The cart is already moving right at 1.2 m s⁻¹ in test B. Explain its subsequent motion using Newton's first law. **[2 marks]**

Answer / mark points: The resultant force is zero, so acceleration is zero. [1] The cart continues at 1.2 m s⁻¹ to the right (constant velocity). [1]

Teacher prompt: "The forces are balanced so it stops" is incorrect. "Constant speed" needs the unchanged direction.

2(e) If the cart is initially at rest in test B, what happens while these forces remain unchanged? **[1 mark]**

Answer / mark points: It remains at rest. [1]



2 Reading the forces on the cart continued

2(f) For test C, calculate the resultant horizontal force. Include its direction. [1 mark]

Answer / mark points: $60 - 20 = 40$ N to the left. [1]

2(g) The cart is moving right in test C. Calculate its acceleration and explain what happens to its speed before it stops. [2 marks]

Answer / mark points: $a = 40 / 40 = 1.0$ m s⁻² to the left. [1] Acceleration opposes its current velocity, so its speed decreases. [1]

Teacher prompt: A leftward resultant does not mean a right-moving cart immediately moves left.

2(h) The robot stops pulling a cart that is moving right. A 30 N resistive force still acts. Is its acceleration zero? Explain. [1 mark]

Answer / mark points: No: the non-zero resultant is 30 N to the left, so it accelerates left (slows down while moving right). [1] Require the force-based reason, not just "no".

3 Setting the robot's pulling force

Use the data in each part. Loads change between tests. The robot pulls horizontally and the cart does not accelerate vertically.

3(a) A loaded cart of mass 30 kg must accelerate at 0.60 m s⁻². Calculate the required resultant force. [1 mark]

Answer / mark points: $F = ma = 30 \times 0.60 = 18$ N forwards. [1]

3(b) The robot pulls a 50 kg cart with 80 N. Resistance is 20 N. Calculate the acceleration. [2 marks]

Answer / mark points: Resultant = $80 - 20 = 60$ N. [1] $a = 60 / 50 = 1.2$ m s⁻² forwards. [1]

3(c) A cart accelerates at 1.5 m s⁻² when the robot pulls with 100 N against 25 N resistance. Calculate the total mass of cart and load. [2 marks]

Answer / mark points: Resultant = $100 - 25 = 75$ N. [1] $m = F / a = 75 / 1.5 = 50$ kg. [1]



3 Setting the robot's pulling force continued

3(d) An empty cart has mass 20 kg and carries an 80 kg load. Resistance is 30 N. Calculate the pulling force needed for an acceleration of 0.50 m s^{-2} . **[2 marks]**

Answer / mark points: Total mass = $20 + 80 = 100 \text{ kg}$; required resultant = $100 \times 0.50 = 50 \text{ N}$. [1]
Pulling force = $50 + 30 = 80 \text{ N}$ forwards. [1]

Teacher prompt: 50 N is the resultant, not the required pulling force. The empty cart also accelerates.

3(e) The robot can exert at most 90 N. Resistance remains 30 N. The required acceleration is at least 0.50 m s^{-2} . Calculate the maximum load on the 20 kg empty cart. **[2 marks]**

Answer / mark points: Available resultant = $90 - 30 = 60 \text{ N}$; maximum total mass = $60 / 0.50 = 120 \text{ kg}$. [1] Maximum load = $120 - 20 = 100 \text{ kg}$. [1]

3(f) A 75 kg loaded cart's velocity increases from 0.40 m s^{-1} to 1.60 m s^{-1} in 3.0 s. Calculate the average resultant force. **[2 marks]**

Answer / mark points: $a = (1.60 - 0.40) / 3.0 = 0.40 \text{ m s}^{-2}$. [1] $F = 75 \times 0.40 = 30 \text{ N}$ forwards. [1]

4 Which object does each force act on

A 6.0 kg crate rests on the warehouse floor. A robot can push it against a fixed stop, but the crate remains stationary.

4(a) The floor exerts an upward contact force on the stationary crate. State the force's magnitude and identify its Newton's third-law partner, including object and direction. **[2 marks]**

Answer / mark points: Upward floor-on-crate contact force = weight = $6.0 \times 10 = 60 \text{ N}$. [1] Its partner is the 60 N downward contact force exerted by the crate on the floor. [1]

4(b) The crate's weight and the upward floor force are equal and opposite. Explain why these are not a third-law pair. **[2 marks]**

Answer / mark points: Both act on the same object, the crate; third-law partners act on different objects. [1] They arise from different interactions: Earth–crate gravity and floor–crate contact. [1]

4(c) While the crate rests against the fixed stop, the robot pushes it with 40 N to the right. State the magnitude and direction of the force the crate exerts on the robot. Name the law used. **[2 marks]**

Answer / mark points: 40 N to the left, on the robot. [1] Newton's third law. [1]



5 Testing the relationship in the laboratory

Figure 2 is a model of the cart. A trolley is connected by a light string over a low-friction pulley to a mass hanger. The runway is level; friction is negligible and the string stays taut. The trolley and hanger move together. Total moving mass means trolley, card, hanger and ALL added masses. The hanger's weight is the driving force on this combined system.

Record speed at G1 and G2

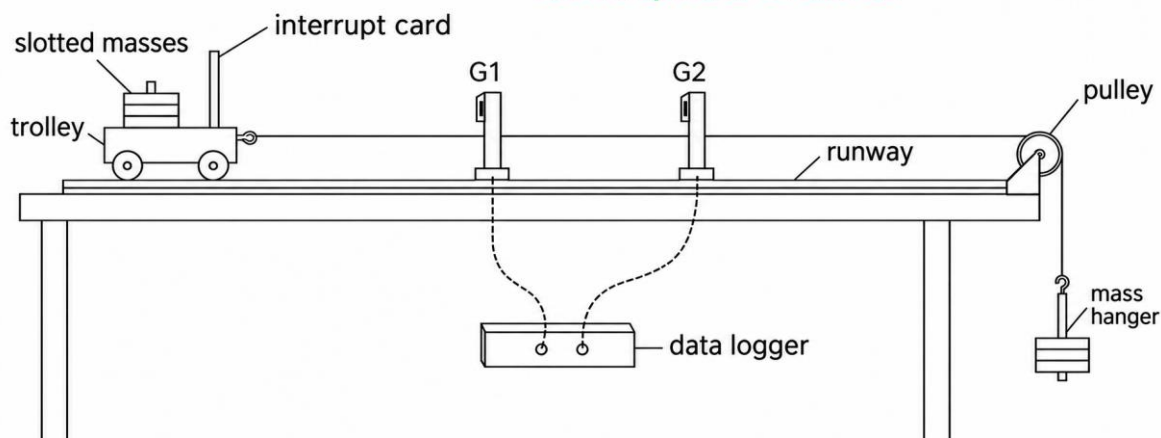


Figure 2

5(a) Explain how the two light gates and data logger can determine the trolley's acceleration. Refer to measured speeds and time. **[2 marks]**

Answer / mark points: Enter the interrupt-card length; each gate gives speed from card length / beam-interruption time, and the logger records the elapsed time between the speed readings. [1] Calculate $a = (\text{speed at G2} - \text{speed at G1}) / \text{elapsed time between readings}$. [1] A logger that directly reports acceleration using these readings is acceptable.

5(b) How can the student increase the driving force without changing the total moving mass? **[2 marks]**

Answer / mark points: Transfer slotted masses from the trolley onto the hanger. [1] The hanger weight increases but the combined trolley-plus-hanger mass remains unchanged. [1]

5(c) The hanger and the masses on it have a total mass of 0.20 kg. Calculate the driving force on the combined system. **[1 mark]**

Answer / mark points: Driving force = hanger weight = $0.20 \times 10 = 2.0 \text{ N}$. [1]

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5 Testing the relationship in the laboratory continued

Table 1

Driving force / N	Mean acceleration / m s^{-2}
1.0	1.0
2.0	2.0
3.0	3.0

5(d) Table 1 was obtained with a fixed total moving mass of 1.0 kg. State the relationship supported by the data and use values to justify it. **[2 marks]**

Answer / mark points: Acceleration is directly proportional to resultant/driving force at constant total mass. [1] For example, doubling force from 1.0 N to 2.0 N doubles acceleration from 1.0 to 2.0 m s^{-2} (or trebling both). [1] A bare “both increase” is insufficient.

5(e) Write a method to investigate both (i) how acceleration depends on force at fixed mass and (ii) how it depends on mass at fixed force. Use Figure 2. Include measurements, controls, repeats, analysis and one safety precaution. **[6 marks]**

Answer / mark points: Model method: Secure the pulley and level runway. Measure the total moving mass with a balance, including trolley, card, hanger and slotted masses. Enter the card length into the logger. Release the trolley without a push from the same position and record the two gate speeds and elapsed time (or logger acceleration). Keep the hanger clear of the floor throughout both gate readings.

For fixed-mass trials, transfer masses from trolley to hanger. Calculate each driving force from the total hanging mass $\times g$ while keeping combined moving mass fixed. Use several force values; repeat each at least three times and calculate mean acceleration. Plot mean acceleration against force; a straight line through the origin supports direct proportionality when friction is negligible.

For fixed-force trials, keep the hanger mass unchanged and add masses to the trolley. Record each new total moving mass and repeat the same measurements. Compare how acceleration changes as mass increases; doubling mass should halve acceleration at the same force. Use a tray beneath the hanger / a catch for the trolley and keep feet clear of falling masses.

Holistic marking: 5–6 marks for a logically ordered, usable method covering BOTH investigations, valid acceleration measurement and correct force/mass controls; 3–4 for a mostly workable plan with an omission or one investigation developed; 1–2 for isolated relevant steps. 0 for no relevant physics. Choose the level, then the mark for completeness and clarity; do not award six automatic ticks.

Teacher prompt: Scaffold: set up $\rightarrow$ measure acceleration $\rightarrow$ vary force/control mass $\rightarrow$ vary mass/control force $\rightarrow$ repeat/analyse $\rightarrow$ safety. Do not equate hanger weight with tension on the trolley.

5(f) At a fixed driving force of 2.0 N, the total moving mass is increased from 1.0 kg to 2.0 kg. Calculate the new acceleration. **[1 mark]**

Answer / mark points: $a = F / m = 2.0 / 2.0 = 1.0 \text{ m s}^{-2}$. [1] It halves from 2.0 m s^{-2} .

5(g) A student times the trolley travelling from rest over the whole runway and calls distance / time its final speed. Explain the mistake and give a better way to measure its final speed. **[2 marks]**

Answer / mark points: Distance / total time gives average speed, not final speed, because the trolley accelerates. [1] Use a light gate near the end and calculate speed from card length / beam-interruption time. [1]

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6 Higher tier only Inertia and inertial mass

The engineer compares an empty cart with the same cart carrying a heavy load.

6(a) State what inertia means. Explain why the loaded cart's velocity changes less than the empty cart's velocity when the same resultant force acts for the same time. **[2 marks]**

Answer / mark points: Inertia is the tendency to remain at rest or continue at constant velocity. [1]
Greater mass means less acceleration under the same resultant, so less velocity change in the same time. [1]

6(b) A test module accelerates at 0.80 m s^{-2} under a resultant force of 16 N. Calculate its inertial mass and state what inertial mass measures. **[2 marks]**

Answer / mark points: Inertial mass = resultant force / acceleration = $16 / 0.80 = 20 \text{ kg}$. [1] It measures how difficult it is to change the module's velocity. [1]

7 Higher tier only Turning at the loading station

Two cables pull a cart at a low-friction loading station: 40 N east and 45 N north. Consider only these horizontal forces. Figure 3: one small square = 5 N. Use a vector scale drawing, not trigonometry.

7(a) Starting at O, draw the two force vectors head-to-tail on Figure 3. Draw and label the resultant force vector. **[3 marks]**

Answer / mark points: Eight squares east from O. [1] Nine squares north from that head. [1]
Labelled resultant arrow from O to final head. [1] Either head-to-tail order accepted.

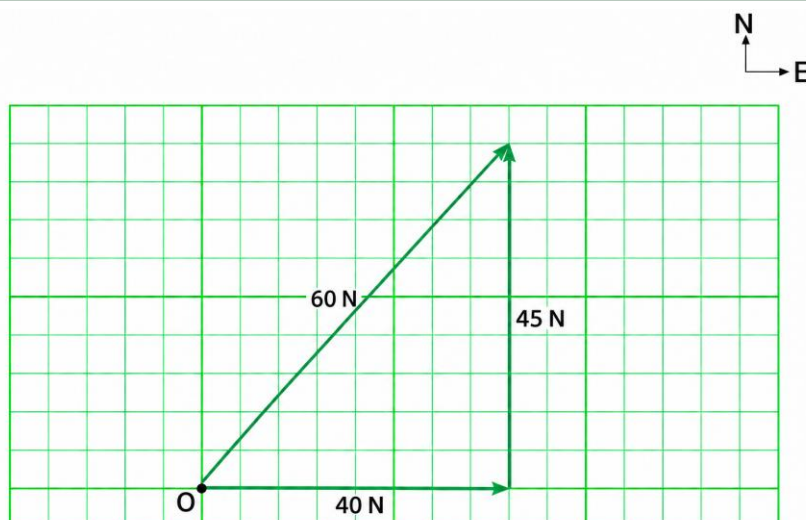


Figure 3

7(b) Use your drawing to determine the resultant force's magnitude and direction. Give the angle north of east. **[2 marks]**

Answer / mark points: Resultant length ≈ 12.0 squares, so magnitude $\approx 60 \text{ N}$. [1; allow 59–62 N from a sound scale drawing] Direction $\approx 48^\circ$ north of east. [1; allow 46–50°]

7(c) A third cable is added so that the cart has zero horizontal resultant force. State the force that this cable must exert, including its direction. **[2 marks]**

Answer / mark points: About 60 N. [1] About 48° south of west, opposite to the original resultant. [1] Accept consistent follow-through in the opposite direction.

Review and improve

Zero resultant means constant velocity, not necessarily rest. For $F = ma$, use the resultant force and the mass of the system it acts on.

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