

Equations and unit conversions

AQA GCSE Physics 8463 and Combined Science Trilogy 8464 | Papers 1 and 2 | Both tiers

Worked solutions and teaching prompts | Core 47 marks | Optional harder mathematics + 9

Skills practised

Change the subject and substitute with appropriate units: MS3b / 3c, 8463 Section 7 / 8464 Section 9

$V = IR$: 8463 4.2.1.3 / 8464 6.2.1.3; density $\rho = m / V$: 8463 4.3.1.1 / 8464 6.3.1.1

$s = vt$: 8463 4.5.6.1.2 / 8464 6.5.4.1.2; $W = Fs$: 8463 4.5.2 / 8464 6.5.2

Energy transfers, $E_k = 0.5mv^2$ and $E_p = mgh$: 8463 4.1.1.1-4.1.1.2 / 8464 6.1.1.1-6.1.1.2

Conservation and dissipation of energy: 8463 4.1.2.1 / 8464 6.1.2.1

A campsite technician checks electrical parts, travel times and water containers before opening the equipment station. Use the results to judge whether the equipment meets the stated limits.

Core 1-6: 30 parts, 47 marks. Optional 7: 4 parts, 9 marks. All equations are shared content; the extension raises mathematical demand. Accept equivalent methods and sensible follow-through. Original PhysicsUK resource, not an official AQA mark scheme.

1 Choosing quantities and units

1(a) A log records the distance a trolley travels and the time taken. Name the quantity calculated by dividing distance by time, and give its SI unit. **[1 mark]**

Answer / mark points: Speed (average speed for the journey), in m s^{-1} . [1] Both quantity and unit are needed.

1(b) A balance reads 750 g for a small equipment pack. Convert this mass to kilograms before using an SI equation. **[1 mark]**

Answer / mark points: $750 / 1000 = 0.750 \text{ kg}$. [1]

2 Electrical checks

Each is a separate test on a resistive component. Use $V = IR$ and the measured values; do not assume that every real component has constant resistance as its temperature changes.

2(a) A test resistor has resistance 5.0Ω and a potential difference of 6.0 V across it. Calculate the current. **[1 mark]**

Answer / mark points: $I = V / R = 6.0 / 5.0 = 1.2 \text{ A}$. [1]



2 Electrical checks continued

2(b) A different component has potential difference 9.0 V and current 0.30 A. Calculate its resistance. **[1 mark]**

Answer / mark points: $R = V / I = 9.0 / 0.30 = 30 \, \Omega$. [1]

2(c) A 40 Ω resistor carries a current of 0.15 A. Calculate the potential difference across it. **[1 mark]**

Answer / mark points: $V = IR = 0.15 \times 40 = 6.0 \, \text{V}$. [1]

2(d) At 6.0 V, another component carries 200 mA. Calculate its resistance, converting the current first. **[2 marks]**

Answer / mark points: 200 mA = 0.200 A. [1]

$R = V / I = 6.0 / 0.200 = 30 \, \Omega$. [1]

Teacher prompt: Using 200 directly gives a resistance 1000 times too small.

2(e) A separate 12 V test uses an 8.0 Ω resistor. Calculate the current. **[1 mark]**

Answer / mark points: $I = V / R = 12 / 8.0 = 1.5 \, \text{A}$. [1]

2(f) A 6.0 V supply can provide at most 0.50 A. Choose between a 10 Ω resistor and a 15 Ω resistor. Calculate the current for each and justify which stays within the limit. Treat both resistances as constant in this test.

[3 marks]

Answer / mark points: For 10 Ω : $I = 6.0 / 10 = 0.60 \, \text{A}$. [1]

For 15 Ω : $I = 6.0 / 15 = 0.40 \, \text{A}$. [1]

Choose 15 Ω : 0.40 A is within the 0.50 A limit; 0.60 A for 10 Ω exceeds it. [1]

2(g) A trainee measures 5.0 V and 0.25 A, then writes $R = I / V = 0.050 \, \Omega$. Correct the resistance and explain the rearrangement error. **[2 marks]**

Answer / mark points: $R = V / I = 5.0 / 0.25 = 20 \, \Omega$. [1] Divide potential difference by current, not current by potential difference; $V = IR$ gives $R = V / I$. [1]



3 Travel times around the campsite

The distances below are distances travelled. Calculate average speed for a complete journey unless another quantity is requested.

3(a) An equipment trolley travels 240 m in 160 s. Calculate its average speed. **[1 mark]**

Answer / mark points: $v = s / t = 240 / 160 = 1.5 \text{ m s}^{-1}$. [1]

3(b) A powered cart travels at 0.80 m s^{-1} for 150 s. Calculate the distance travelled. **[1 mark]**

Answer / mark points: $s = vt = 0.80 \times 150 = 120 \text{ m}$. [1]

3(c) A trolley travels 180 m at a constant speed of 1.2 m s^{-1} . Calculate the journey time. **[1 mark]**

Answer / mark points: $t = s / v = 180 / 1.2 = 150 \text{ s}$. [1]

3(d) A worker moves a cart 360 m in 3.0 min. Calculate its average speed in m s^{-1} . **[2 marks]**

Answer / mark points: 3.0 min = 180 s. [1]

$v = s / t = 360 / 180 = 2.0 \text{ m s}^{-1}$. [1]

3(e) Another cart travels 0.60 km at 2.5 m s^{-1} . Calculate the travel time in minutes. **[3 marks]**

Answer / mark points: 0.60 km = 600 m. [1]

$t = s / v = 600 / 2.5 = 240 \text{ s}$. [1]

$240 / 60 = 4.0 \text{ min}$. [1]

3(f) The next collection is 600 m away and must be reached within 4.0 min. A cart cannot exceed 2.0 m s^{-1} . Can it arrive in time even if it travels at this speed throughout? Use a calculation to justify your answer. **[2 marks]**

Answer / mark points: Fastest time = $600 / 2.0 = 300 \text{ s} = 5.0 \text{ min}$. [1] No: 5.0 min exceeds the 4.0 min deadline. [1] Alternatively, the required speed is $600 / 240 = 2.5 \text{ m s}^{-1}$, above its limit.



4 Containers and maintenance liquids

Use the mass and volume of the liquid itself. Container mass must not be included when finding the liquid density.

4(a) A maintenance liquid has mass 1.6 kg and volume 0.0020 m³. Calculate its density. **[1 mark]**

Answer / mark points: $\rho = m / V = 1.6 / 0.0020 = 800 \text{ kg m}^{-3}$. [1]

4(b) Water has density 1000 kg m⁻³. Calculate the mass of 0.0030 m³ of water. **[1 mark]**

Answer / mark points: $m = \rho V = 1000 \times 0.0030 = 3.0 \text{ kg}$. [1]

4(c) A liquid fuel has density 800 kg m⁻³ and mass 2.4 kg. Calculate its volume in m³. **[1 mark]**

Answer / mark points: $V = m / \rho = 2.4 / 800 = 0.0030 \text{ m}^3$. [1]

4(d) A water sample has mass 2500 g and volume 0.0025 m³. Calculate its density in kg m⁻³. **[2 marks]**

Answer / mark points: 2500 g = 2.5 kg. [1]

$\rho = m / V = 2.5 / 0.0025 = 1000 \text{ kg m}^{-3}$. [1]

4(e) A waterproof sample block has mass 96 g and volume 120 cm³. Calculate its density in kg m⁻³. Convert both measurements to SI units. **[3 marks]**

Answer / mark points: 96 g = 0.096 kg. [1]

120 cm³ = 120 / 1000000 = 0.000120 m³. [1]

$\rho = 0.096 / 0.000120 = 800 \text{ kg m}^{-3}$. [1]

Teacher prompt: 1 cm³ is 0.000001 m³, not 0.01 m³. The conversion applies to volume, not length.

4(f) An empty bottle has mass 0.20 kg. Filled with 750 cm³ of cleaning liquid, its total mass is 1.10 kg. Calculate the density of the liquid in kg m⁻³. **[3 marks]**

Answer / mark points: Liquid mass = 1.10 - 0.20 = 0.90 kg. [1]

750 cm³ = 0.000750 m³. [1]

$\rho = 0.90 / 0.000750 = 1200 \text{ kg m}^{-3}$. [1]

Teacher prompt: Use net liquid mass, not the combined mass of the bottle and liquid.

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5 Moving and raising equipment

Use the supplied force acting along the movement for work done. For gravitational potential energy, use the vertical rise and $g = 10 \text{ N kg}^{-1}$.

5(a) A worker pulls a crate 2.5 m with a constant 140 N force along its movement. Calculate the work done by this force. **[1 mark]**

Answer / mark points: $W = Fs = 140 \times 2.5 = 350 \text{ J}$. [1]

5(b) A 35 N force along the movement does 84 J of work. Calculate the distance moved. **[1 mark]**

Answer / mark points: $s = W / F = 84 / 35 = 2.4 \text{ m}$. [1]

5(c) A constant force does 120 J of work while acting along a 300 cm movement. Calculate the force. **[2 marks]**

Answer / mark points: $300 \text{ cm} = 3.0 \text{ m}$. [1]

$F = W / s = 120 / 3.0 = 40 \text{ N}$. [1]

5(d) The hoist raises a 4.0 kg equipment pack through a vertical height of 1.5 m. Calculate its increase in gravitational potential energy. **[1 mark]**

Answer / mark points: $E_p = mgh = 4.0 \times 10 \times 1.5 = 60 \text{ J}$. [1]

5(e) A 6.0 kg load gains 180 J of gravitational potential energy. Calculate its vertical rise. **[1 mark]**

Answer / mark points: $h = E_p / (mg) = 180 / (6.0 \times 10) = 3.0 \text{ m}$. [1]



6 An independent check of the water hoist

Figure 1 shows one sealed canister before and after a vertical lift. The dashed outline is its initial position, not a second canister. The empty canister has mass 0.60 kg and contains 0.0024 m³ of water of density 1000 kg m⁻³.

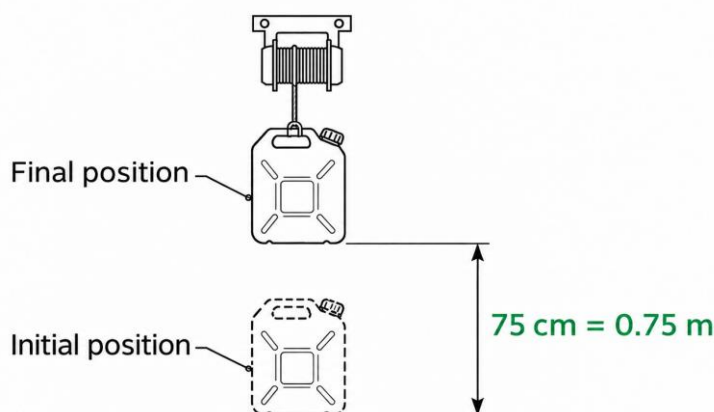


Figure 1

6(a) Use the water volume and density given above to calculate the total mass of the filled canister, including the empty canister. **[2 marks]**

Answer / mark points: Water mass = $\rho V = 1000 \times 0.0024 = 2.4$ kg. [1]
Total mass = $2.4 + 0.60 = 3.0$ kg. [1]

6(b) Use the vertical rise shown in Figure 1 to calculate the increase in gravitational potential energy of the filled canister. **[2 marks]**

Answer / mark points: 75 cm = 0.75 m. [1]
 $E_p = mgh = 3.0 \times 10 \times 0.75 = 22.5$ J. [1]

6(c) For an ideal steady lift without friction, the useful work equals this increase in gravitational potential energy. Use your result and $W = Fs$ to calculate the constant upward lifting force. **[1 mark]**

Answer / mark points: $F = W / s = 22.5 / 0.75 = 30$ N. [1] Equivalent method: $F = mg = 3.0 \times 10 = 30$ N.

6(d) The real hoist receives 30.0 J of energy during this lift. The canister and hoist start and finish at rest. Apart from the gravitational energy increase, the remaining energy is transferred by friction. Calculate the energy dissipated and identify the energy stores it increases. **[2 marks]**

Answer / mark points: Energy dissipated = $30.0 - 22.5 = 7.5$ J. [1] Friction transfers it to the thermal energy stores of the hoist and surroundings. [1]

Teacher prompt: Energy is transferred, not used up or destroyed. The unchanged kinetic energy matters in this account.



7 Optional harder mathematics

These square and square-root rearrangements use shared course equations. They are not a separate Higher-only specification block.

7(a) Optional: a 5.0 kg cart has kinetic energy 3.6 J. Rearrange the kinetic-energy equation and calculate its speed. **[2 marks]**

Answer / mark points: $v^2 = 2E_k / m = 2 \times 3.6 / 5.0 = 1.44 \text{ m}^2 \text{ s}^{-2}$. [1]

Taking the positive square root gives $v = 1.2 \text{ m s}^{-1}$. [1]

Teacher prompt: Find the square of the speed first, then take the square root. Speed is non-negative.

7(b) Optional: another trolley has kinetic energy 9.0 J when moving at 0.60 m s^{-1} . Rearrange the equation and calculate its mass. **[2 marks]**

Answer / mark points: $m = 2E_k / v^2$. [1]

$m = 2 \times 9.0 / 0.60^2 = 50 \text{ kg}$. [1]

7(c) Optional: a 35 kg cart has kinetic energy 300 J. Its permitted speed is at most 4.0 m s^{-1} . Calculate its speed and decide whether it meets the limit. **[3 marks]**

Answer / mark points: $v^2 = 2 \times 300 / 35 = 17.1429 \text{ m}^2 \text{ s}^{-2}$. [1]

Positive square root gives $v = 4.14 \text{ m s}^{-1}$ (about 4.1 m s^{-1}). [1]

It exceeds 4.0 m s^{-1} , so does not meet the limit. [1]

Teacher prompt: A useful check is that energy at the speed limit is $0.5 \times 35 \times 4.0^2 = 280 \text{ J}$, below 300 J. The question still asks for the actual speed.

7(d) Optional: a trolley speed is tripled while its mass stays the same. By what factor does its kinetic energy increase? Explain using the equation. **[2 marks]**

Answer / mark points: It increases by a factor of 9. [1] E_k is proportional to v^2 at constant mass, so tripling speed multiplies the kinetic energy by $3^2 = 9$. [1]

Review and improve

Check the physical quantity and unit before substituting. Convert volume units with a cubic factor, not a length factor. Square the speed before using kinetic energy; take the positive square root when finding speed. Use numerical results to justify the stated decision.

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