

Paper 1 multistep calculation practice

AQA GCSE Combined Science Trilogy 8464 and Separate Physics 8463 | Paper 1 | Both tiers

Worked answers and marking guidance | 26 parts | 41 marks

Specification points covered

8463 4.1.1.2 / 8464 6.1.1.2: kinetic, elastic and gravitational energy
 8463 4.1.1.3 / 8464 6.1.1.3: thermal energy changes and specific heat capacity
 8463 4.1.1.4 / 8464 6.1.1.4: power and energy transfer
 8463 4.1.2.2 / 8464 6.1.2.2: efficiency
 8463 4.2.1.2 / 8464 6.2.1.2: current, charge and time
 8463 4.2.1.3 / 8464 6.2.1.3: potential difference, current and resistance
 8463 4.2.4.1 / 8464 6.2.4.1: electrical power
 8463 4.3.1.1 / 8464 6.3.1.1: density, mass and volume

An emergency team must light a field station, warm water and lift supplies. Its 24 V power pack can deliver 0.90 MJ of usable electrical energy and a maximum total power of 600 W. Treat these as separate limits.

Original PhysicsUK practice, not an official AQA paper or mark scheme. Credit correct alternative methods and consistent error carried forward. The power-pack capacity is usable electrical output, not chemical energy before internal losses.

1 Reading the power-pack limits

Figure 1 shows electrical energy going to the equipment. It is an energy-flow schematic, not a circuit diagram.

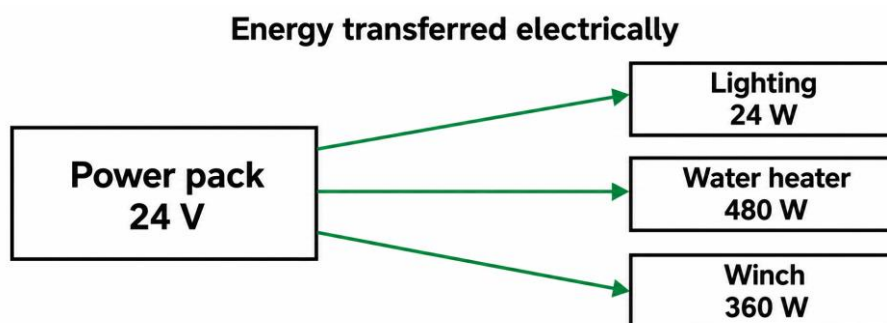


Figure 1

1(a) Write the usable electrical energy capacity of 0.90 MJ in joules. **[1 mark]**

Answer / mark points: $0.90 \times 1\,000\,000 = 900\,000\text{ J}$. [1]

1(b) A volunteer says the 600 W label tells the team how much energy the pack can deliver in total. Explain why this is wrong. **[2 marks]**

Answer / mark points: 600 W is a rate of energy transfer: at most 600 J each second. [1] The total usable energy is 900 000 J; it is a different quantity and does not specify the allowed rate on its own. [1]



2 Keeping the station lit

All equipment receives a steady 24 V. Lighting draws 24 W throughout a six-hour shift. Assume steady ratings and neglect extra lead or control losses. The separate beacon test in 2(b)–2(c) does not use the shift's power pack.

2(a) Use the lighting rating to calculate the current drawn by the lighting. **[1 mark]**

Answer / mark points: $P = VI$, so $I = P / V = 24 / 24 = 1.0$ A. [1]

2(b) In a separate bench test, 240 C passes through a beacon in 5.0 minutes. Calculate its mean current. **[2 marks]**

Answer / mark points: $t = 5.0 \times 60 = 300$ s. [1]

$I = Q / t = 240 / 300 = 0.80$ A. [1]

2(c) The beacon has 24 V across it. Use the current from 2(b) to calculate its electrical power. **[1 mark]**

Answer / mark points: $P = VI = 24 \times 0.80 = 19.2$ W. [1] Accept 19 W to 2 significant figures.

2(d) Calculate the charge flow through the lighting during the full six-hour shift. **[2 marks]**

Answer / mark points: $t = 6 \times 3600 = 21\,600$ s. [1]

$Q = It = 1.0 \times 21\,600 = 21\,600$ C. [1]

2(e) Calculate the electrical energy needed for six hours of lighting. Keep the answer in joules for the final budget. **[1 mark]**

Answer / mark points: $E = Pt = 24 \times 21\,600 = 518\,400$ J. [1] Accept $E = VIt$ as an alternative. Use the time already converted in 2(d); retain the unrounded value for section 6.



3 Warming the water supply

Use Table 1. The heater draws 480 W and transfers 75% of its electrical input energy to the water. The water remains liquid with no mass loss. The stated efficiency already accounts for energy not transferred to the water.

Table 1

Water-heating data	Value
Water volume	2.0 litres
Water density	1000 kg/m ³
Specific heat capacity of water	4200 J kg ⁻¹ °C ⁻¹
Initial temperature	12 °C
Target temperature	42 °C

3(a) The water volume is 2.0 litres. Calculate its mass using the density in Table 1. Use 1 litre = 0.001 m³. **[2 marks]**

Answer / mark points: $V = 2.0 \times 0.001 = 0.0020 \text{ m}^3$. [1]
 $m = \rho V = 1000 \times 0.0020 = 2.0 \text{ kg}$. [1]

3(b) Calculate the temperature rise needed to reach the target temperature. **[1 mark]**

Answer / mark points: $\Delta\theta = 42 - 12 = 30 \text{ °C}$. [1] Use the change, not the final temperature.

3(c) Calculate the increase in thermal energy of the water. **[1 mark]**

Answer / mark points: $\Delta E = mc\Delta\theta = 2.0 \times 4200 \times 30 = 252\,000 \text{ J}$. [1]

3(d) Calculate the electrical input energy needed when the heating efficiency is 75%. **[2 marks]**

Answer / mark points: Efficiency = useful energy / input energy; input energy = $252\,000 / 0.75$. [1]
 for correct rearrangement and decimal efficiency]
 Input energy = 336 000 J. [1]

Teacher prompt: Divide the useful output by 0.75; multiplying would make the input smaller than the useful output.

3(e) The heater draws 480 W at 24 V. Calculate its operating current and then its resistance at this operating point. **[2 marks]**

Answer / mark points: $I = P / V = 480 / 24 = 20 \text{ A}$. [1]
 $R = V / I = 24 / 20 = 1.2 \text{ } \Omega$. [1] Accept $R = V^2 / P = 24^2 / 480$ with a valid intermediate relation for both marks.



3 Warming the water supply continued

3(f) Use the electrical input energy from 3(d) and the 480 W rating to calculate the heating time. **[1 mark]**

Answer / mark points: $t = E / P = 336\,000 / 480 = 700$ s. [1] The rating is electrical input power.

3(g) A volunteer predicts 525 s by dividing 252 000 J by 480 W. Explain why this prediction is too short. Use the efficiency in your answer. **[2 marks]**

Answer / mark points: The calculation treats all 480 W as useful heating of the water, ignoring the 75% efficiency. [1] Only $0.75 \times 480 = 360$ W heats the water, so the actual time is $252\,000 / 360 = 700$ s, longer than 525 s. [1]

4 Lifting the supplies

The total raised mass is 50 kg. Each lift raises it vertically by 6.0 m, using an 18 m cable. Take $g = 9.8$ N/kg. The load starts and finishes at rest. The winch draws 360 W and has an efficiency of 70% for this lift.

4(a) Calculate the gain in gravitational potential energy during one lift. Select the relevant distance from the information above. **[1 mark]**

Answer / mark points: $E_p = mgh = 50 \times 9.8 \times 6.0 = 2940$ J. [1] The 6.0 m vertical rise is needed, not the 18 m cable length.

4(b) Calculate the electrical input energy for one lift at 70% efficiency. **[2 marks]**

Answer / mark points: Input energy = useful energy / efficiency = $2940 / 0.70$. [1]
Input energy = 4200 J. [1]

4(c) Calculate the electrical energy needed for six identical lifts. **[1 mark]**

Answer / mark points: $6 \times 4200 = 25\,200$ J. [1] Retain this unrounded value for the final budget.

4(d) Calculate the time for one lift using the winch's 360 W electrical input rating. **[1 mark]**

Answer / mark points: $t = \text{input energy} / \text{input power} = 4200 / 360 = 11.666\dots$ s, about 11.7 s. [1]
Accept 12 s to 2 significant figures. Do not divide 2940 J by the electrical input power.



5 Checking the trolley buffer

A loaded trolley has a total mass of 25 kg and approaches a spring buffer at 1.2 m s^{-1} . The buffer has spring constant 3600 N/m and must not compress by more than 10 cm. It obeys the spring-energy equation over this range. Use an ideal model in which the trolley's lost kinetic energy is stored in the spring. This safety calculation is not an electrical load on the pack.

5(a) Calculate the trolley's kinetic energy as it approaches the buffer. **[1 mark]**

Answer / mark points: $E_k = 0.5mv^2 = 0.5 \times 25 \times 1.2^2 = 18 \text{ J}$. [1]

5(b) Could the buffer store all of this kinetic energy without exceeding 10 cm compression? Calculate the spring energy at 10 cm and compare it with the trolley's kinetic energy. **[2 marks]**

Answer / mark points: $e = 10 \text{ cm} = 0.10 \text{ m}$; elastic energy $= 0.5 \times 3600 \times 0.10^2 = 18 \text{ J}$. [1 for correct SI calculation]

Yes, just: 18 J equals the trolley's 18 J kinetic energy in the ideal model. [1] This is a calculation within the stated model, not a real-world safety certification.

5(c) The trolley approaches at twice the original speed, with the same mass. Calculate its new kinetic energy and decide whether the same 10 cm buffer limit is sufficient. **[2 marks]**

Answer / mark points: New speed $= 2.4 \text{ m s}^{-1}$; $E_k = 0.5 \times 25 \times 2.4^2 = 72 \text{ J}$ (four times larger). [1]

No: 72 J exceeds the 18 J that can be stored at 10 cm compression. [1] Accept the squared-speed ratio route: doubling speed multiplies kinetic energy by four.

6 Can the pack finish the shift

The jobs are six hours of lighting, one heating batch from section 3, and six lifts from section 4. The pack starts with 0.90 MJ of usable electrical energy. No recharging occurs. Include only these three jobs in the budget.

6(a) A volunteer switches on the lighting, heater and winch together. Calculate their total power demand and determine whether it is within the 600 W limit. **[2 marks]**

Answer / mark points: Total $= 24 + 480 + 360 = 864 \text{ W}$. [1]

864 W exceeds 600 W, so this combination is not allowed. [1]



6 Can the pack finish the shift continued

6(b) The lighting must remain on. Describe an operating schedule that allows both heating and lifting without exceeding 600 W. Support your answer with the two relevant power totals. **[2 marks]**

Answer / mark points: Run the heater with the lighting while the winch is off: $480 + 24 = 504$ W, below 600 W. [1] Switch the heater off before running the winch with the lighting: $360 + 24 = 384$ W, below 600 W. [1] The reverse order is equally valid. Heating and winching must not overlap.

6(c) Calculate the total electrical energy for the six-hour lighting shift, one heating batch and six lifts. Decide whether 0.90 MJ is enough and calculate the energy remaining. **[2 marks]**

Answer / mark points: Total = $518\,400 + 336\,000 + 25\,200 = 879\,600$ J. [1]
Yes: 879 600 J is less than 900 000 J; remaining energy = 20 400 J. [1] This meets the energy budget only if a schedule such as 6(b) also meets the power limit.

6(d) A volunteer claims the pack can support seven hours of lighting as well as the same heating batch and six lifts. Test the claim with a calculation. **[2 marks]**

Answer / mark points: Seven-hour lighting energy = $24 \times 7 \times 3600 = 604\,800$ J; total = $604\,800 + 336\,000 + 25\,200 = 966\,000$ J. [1 for a correct total]
The claim is false: this exceeds 900 000 J by 66 000 J. [1] Alternative: an extra hour needs 86 400 J, greater than the 20 400 J remaining after six hours.

6(e) After allowing energy for the heating batch and six lifts, calculate the maximum total lighting time in seconds. This includes the original six-hour shift. **[2 marks]**

Answer / mark points: Energy available for lighting = $900\,000 - 336\,000 - 25\,200 = 538\,800$ J. [1]
 $t = E / P = 538\,800 / 24 = 22\,450$ s. [1] This is about 6.24 hours. Alternative: six hours plus $20\,400 / 24 = 850$ additional seconds. Do not count the beacon bench test or the trolley's mechanical energy as electrical shift loads.

Review and improve

Use the answers to identify the pupil's weakest calculation strand: electricity, density and heating, mechanical energy, or the final budget. Separate a conversion error from equation selection. Power limits apply at an instant; energy capacity limits total use. Timing is an estimate awaiting classroom trial. No required-practical completion claim.

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