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SOLUTIONS

ATTEMPT CHECK CORRECT IMPROVE

OCR A AS Electrical Power and Energy solutions

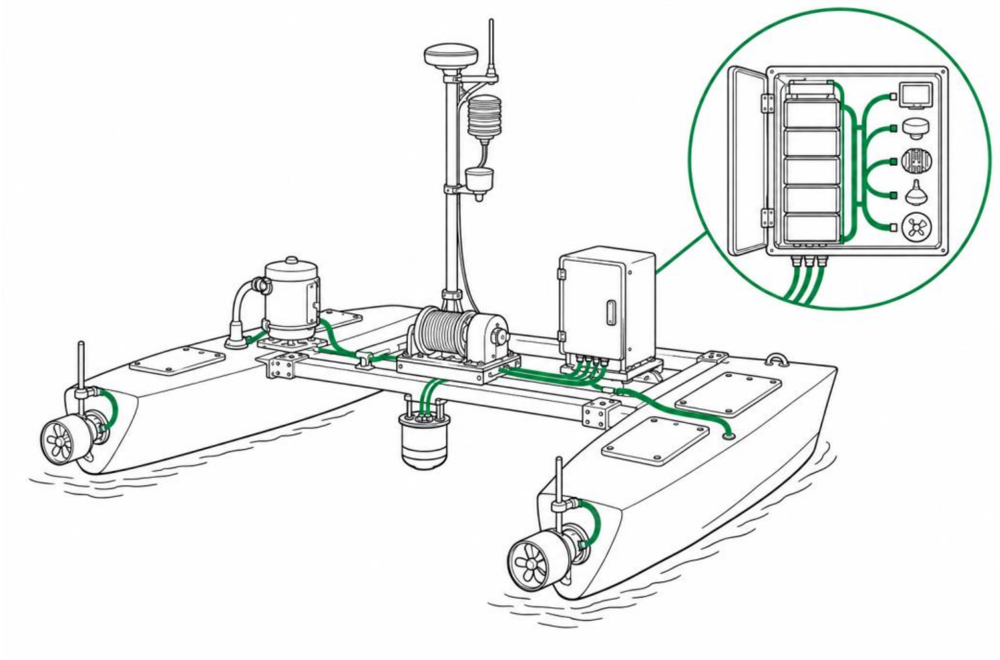
Matching solutions and teaching prompts for the class review

Specification points covered

- 4.2.5(a) Use and apply power equations $P = IV$, $P = I^2R$, and $P = V^2 / R$.
- 4.2.5(b) Use energy transfer equation $W = VIt$.
- 4.2.5(c) Recognise the kilowatt-hour (kWh) as a unit of energy and calculate the cost of electrical energy.

Teaching focus

Require pupils to name the energy transfer or component represented by a calculated power rather than treating every P value as the same physical quantity.
Insist on consistent time units: seconds for joules from $W = VIt$, and hours for energy in kWh.



Context diagram: the Pelagia autonomous survey vessel and its battery distribution system.

1. Electrical power in vessel systems

1. State what is meant by electrical power. [1 mark]

Answer / mark points: Electrical power is the rate of energy transfer, or energy transferred per unit time.

Teacher prompt / common error: Use 'rate of energy transfer'. Power is not the amount of energy stored or used.

2. The sonar array draws a current of 2.40 A from the vessel's 96.0 V supply. Calculate its electrical power. [1 mark]

Answer / mark points: $P = IV = 2.40 \times 96.0 = 230.4$ W, so $P = 230$ W to three significant figures.

Teacher prompt / common error: Multiply the p.d. by the current and keep the final unit as watts.

3. The thruster control unit transfers electrical energy at 1.80 kW from the 96.0 V supply. Calculate its operating current and select the most suitable fuse from 15 A, 20 A and 25 A. [2 marks]

Answer / mark points: 1.80 kW = 1800 W. $I = P/V = 1800/96.0 = 18.75$ A, so 18.8 A. The 20 A fuse is the smallest rating above the normal operating current.

Teacher prompt / common error: Convert kW to W before finding current. A fuse must allow normal operation but should be the smallest suitable higher rating.

4. An instrument-bay heater is rated at 720 W when connected to a 48.0 V converter. Calculate the heater resistance and current. Use your values to verify the power using $P = I^2R$. [3 marks]

Answer / mark points: $R = V^2/P = 48.0^2/720 = 3.20\ \Omega$. $I = P/V = 720/48.0 = 15.0$ A. Check: $I^2R = 15.0^2 \times 3.20 = 720$ W.

Teacher prompt / common error: Use the equation that matches the known quantities. The final I^2R result is a check, not a new assumption.

2. Energy transfer and cable heating

5. The heater in Question 4 operates for 7.5 minutes. Calculate the energy transferred in joules using W = VIt. [2 marks]

Answer / mark points: $t = 7.5 \times 60 = 450$ s. $W = VIt = 48.0 \times 15.0 \times 450 = 3.24 \times 10^5$ J.

Teacher prompt / common error: Convert minutes to seconds because W = VIt gives joules when SI units are used.

6. Explain the difference between electrical power and electrical energy, using the heater as an example. [2 marks]

Answer / mark points: Power is the rate at which the heater transfers energy, measured in watts. Energy is the total transferred during an interval, so the same 720 W heater transfers more energy when it operates for longer.

Teacher prompt / common error: Keep rate and total separate. A high-power device can transfer little energy if it runs briefly.

7. The deck winch takes a current of 14.0 A. Its supply cable has resistance 0.420 Ω. Calculate the thermal power transferred in the cable and the energy transferred to the cable during a 6.0 minute lift. Give the energy in kJ. [2 marks]

Answer / mark points: $P_{cable} = I^2R = 14.0^2 \times 0.420 = 82.3$ W. In 6.0 min, $t = 360$ s, so $W = Pt = 82.3 \times 360 = 2.96 \times 10^4$ J = 29.6 kJ.

Teacher prompt / common error: Use the cable resistance, not the motor resistance, and convert the final joule value to kJ.

8. Explain why $P = I^2R$ is useful for the heating of the winch cable, while P = IV is used for the total electrical input to the winch motor. [2 marks]

Answer / mark points: I^2R gives the rate of thermal energy transfer in a component with resistance R when its current is known. IV gives the total rate of electrical energy supplied to the motor; not all of that input is dissipated as heat in the cable.

Teacher prompt / common error: Do not assume the motor's complete electrical input becomes thermal energy in its supply cable.

3. Mission energy budget

9. The table shows the electrical loads during an 8.0 h survey. Calculate the total operating time in hours for the sampling pump and for the thruster system. **[2 marks]**

Device	Power / kW	Operating pattern during an 8.0 h mission
Sonar array	0.230	continuous
Sampling pump	0.720	25 min in every hour
Thruster system	1.80	62% of the mission
Data computer	0.160	continuous

Answer / mark points: Sampling pump: 25 min × 8 = 200 min = 3.33 h. Thruster system: 0.62 × 8.0 = 4.96 h.

Teacher prompt / common error: A duty fraction multiplies total time. Repeated minutes must be totalled and then converted to hours.

10. Calculate the energy used by each device in the table and hence the total mission energy in kWh. **[4 marks]**

Answer / mark points: Sonar: 0.230 × 8.0 = 1.84 kWh. Pump: 0.720 × 3.33 = 2.40 kWh. Thrusters: 1.80 × 4.96 = 8.93 kWh. Computer: 0.160 × 8.0 = 1.28 kWh. Total = 14.45 kWh, or 14.4 kWh to three significant figures.

Teacher prompt / common error: Use energy in kWh = power in kW × time in h. Add the unrounded values before rounding the total.

4. Battery capacity and charging cost

11. The battery stores 18.0 kWh when fully charged. The control system must leave 15% of this energy unused as a reserve. Determine whether the mission can be completed while keeping the reserve, and calculate the remaining energy margin. **[2 marks]**

Answer / mark points: Usable energy = 0.85 × 18.0 = 15.3 kWh. This exceeds 14.45 kWh, so the mission can be completed. Margin = 15.3 − 14.45 = 0.85 kWh.
Teacher prompt / common error: A 15% reserve means only 85% of the stated battery energy is available for the mission.

12. At the harbour, electrical energy costs £0.31 per kWh. Calculate the charging cost represented by one mission's energy use and the cost for 120 identical missions. **[2 marks]**

Answer / mark points: Using the unrounded mission energy, one mission costs 14.448 × £0.31 = £4.47888, so £4.48. For 120 missions, cost = 120 × 14.448 × £0.31 = £537.4656, so £537.47.
Teacher prompt / common error: The tariff is per kWh. Keep pence and pounds consistent and use an unrounded mission energy where possible.

5. Heating and resistance

13. A corroded connector carries an approximately constant current of 25.0 A. Its resistance increases from 0.0120 Ω to 0.0300 Ω. Calculate the power transferred in the connector before and after corrosion, and determine the factor by which the power increases. [3 marks]

Answer / mark points: Before corrosion, $P = I^2R = 25.0^2 \times 0.0120 = 7.50$ W. After corrosion, $P = 25.0^2 \times 0.0300 = 18.75$ W. Increase factor = 18.75/7.50 = 2.50.

Teacher prompt / common error: At fixed current, resistive heating is directly proportional to resistance.

14. Explain why the increased connector resistance in Question 13 creates a risk of further heating when the current remains approximately constant. [2 marks]

Answer / mark points: At approximately constant current, $P = I^2R$, so the larger resistance transfers more energy each second to the connector. Its temperature therefore rises more quickly and continued deterioration may increase the contact resistance further.

Teacher prompt / common error: Identify the equation and explain the physical consequence: more energy transferred per second causes a faster temperature rise.

15. Two test resistors are connected separately across 96.0 V. Resistor A has resistance 24.0 Ω and resistor B has resistance 18.0 Ω. Calculate the power transferred in each and identify which transfers energy at the greater rate. [2 marks]

Answer / mark points: $P_A = V^2/R_A = 96.0^2/24.0 = 384$ W. $P_B = 96.0^2/18.0 = 512$ W. Resistor B transfers energy at the greater rate.

Teacher prompt / common error: At the same p.d., the smaller resistance has the larger power because $P = V^2/R$.

6. Operating data and equipment choice

16. A floodlight is labelled 240 W. During a test it takes 2.35 A from 96.0 V. Calculate its measured power and the percentage by which this is below the labelled value. **[2 marks]**

Answer / mark points: $P = IV = 96.0 \times 2.35 = 225.6$ W. Percentage below label = $[(240 - 225.6)/240] \times 100 = 6.0\%$.	
Teacher prompt / common error: Calculate the difference from the labelled value, then divide by the labelled value.	

17. An emergency pump must transfer at least 1.20 MJ of electrical energy during an 18 minute test without taking more than 16.0 A from the 96 V supply. Use the manufacturer data to evaluate all three candidates and select the only suitable pump. **[4 marks]**

Candidate	Manufacturer data at 96 V
A	operating current 12.0 A
B	resistance 5.50 Ω
C	rated power 1.05 kW

Answer / mark points: Candidate A: $P = IV = 96 \times 12.0 = 1152$ W and $W = Pt = 1152 \times 1080 = 1.244 \times 10^6$ J, so it meets both limits. Candidate B: $I = V/R = 96/5.50 = 17.5$ A, so it exceeds 16.0 A. Candidate C: $I = P/V = 1050/96 = 10.9$ A, but $W = 1050 \times 1080 = 1.134 \times 10^6$ J, below 1.20 MJ. Only candidate A is suitable.

Teacher prompt / common error: Every candidate must satisfy both conditions. Reject a device as soon as a calculated current or energy fails a limit.

Language and method check

Power is the rate of energy transfer; energy is the total transferred over a time interval.
A device transfers energy. Do not say that it 'uses power over time' when the quantity being calculated is energy.
At constant current, $P = I^2R$ increases with resistance. At constant p.d., $P = V^2/R$ decreases with resistance.