physics UK

Smarter practice. Stronger understanding

SOLUTIONS

ATTEMPT CHECK CORRECT IMPROVE

OCR A AS Resistivity 1 Calculations and Applications solutions

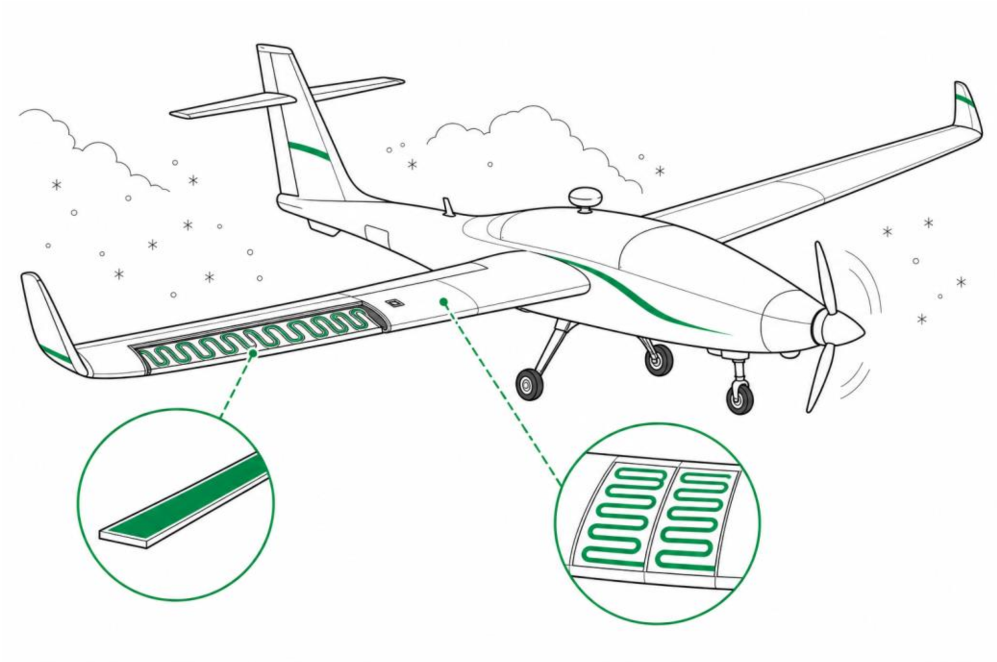
Matching solutions and teaching prompts for the class review

Specification points covered

- 4.2.4(a)(i) Define resistivity using R = ρL / A.
- 4.2.4(b) Describe variation of resistivity of metals and semiconductors with temperature.
- 4.2.5(a) Use and apply power equations P = IV, $P = I^2R$, and $P = V^2 / R$.

Teaching focus

Insist that A is the cross-sectional area perpendicular to current and that temperature is stated when materials are compared.
Credit working that separates geometry, resistance and circuit power rather than treating ρ as another name for R.



Context diagram: a polar survey aircraft, rectangular heater ribbon and twin anti-icing panels.

1. Resistivity and conductor geometry

1. Define resistivity and state its SI unit. [2 marks]

Answer / mark points: Resistivity is the constant ρ in R = ρL/A for a uniform material at a stated temperature. Its SI unit is Ω m.

Teacher prompt / common error: Do not define resistivity as resistance alone. The material property and Ω m unit are both needed.

2. The resistance of a uniform conductor is modelled by R = ρL/A. State what area A represents and explain why the relation applies only when the conductor is uniform. [2 marks]

Answer / mark points: A is the cross-sectional area perpendicular to the current. The relation assumes one material and a constant cross-section, so the same ρ and A apply throughout the stated length.

Teacher prompt / common error: Area is perpendicular to current; it is not the exposed surface area of the whole ribbon.

3. A round constantan lead has length 6.2 m, diameter 0.32 mm and resistivity 4.9×10^{-7} Ω m. Calculate its resistance. [2 marks]

Answer / mark points: $A = \pi(d/2)^2 = \pi(0.320 \times 10^{-3}/2)^2 = 8.04 \times 10^{-8}$ m^2. $R = \rho L/A = (4.9 \times 10^{-7} \times 6.2)/(8.04 \times 10^{-8}) = 37.8\ \Omega$, so 38 Ω.

Teacher prompt / common error: Convert millimetres before squaring and halve the diameter before using πr^2.

2. Direct calculations and scaling

4. One flat anti-icing ribbon has length 8.4 m, width 2.8 mm, thickness 45 μm and resistivity 1.15×10^{-6} Ω m. Calculate its resistance. [3 marks]

Answer / mark points: $A = wt = (2.8 \times 10^{-3})(45 \times 10^{-6}) = 1.26 \times 10^{-7}$ m^2. $R = (1.15 \times 10^{-6} \times 8.4)/(1.26 \times 10^{-7}) = 76.7$ Ω.	
Teacher prompt / common error: A flat ribbon uses width × thickness, not πr^2.	

5. A replacement ribbon must have resistance 64 Ω. It is made from the same material, with length 8.4 m and width 2.8 mm. Calculate the required thickness in μm. [3 marks]

Answer / mark points: $t = \rho L/(Rw) = (1.15 \times 10^{-6} \times 8.4)/[64(2.8 \times 10^{-3})] = 5.39 \times 10^{-5}$ m = 53.9 μm, so about 54 μm.	
Teacher prompt / common error: Keep thickness as the unknown until the final conversion to micrometres.	

6. Two round wires are made from the same material. Wire Q is twice the length of wire P and has half its diameter. Determine R_Q/R_P. [2 marks]

Answer / mark points: R is proportional to L/d^2 for round wires of one material. $R_Q/R_P = 2/(0.5)^2 = 8$.	
Teacher prompt / common error: Halving diameter quarters area, so it multiplies resistance by four before the length change is included.	

3. Material meaning and comparison

7. A test sample has length 0.850 m and diameter 0.360 mm. The p.d. across it is 5.60 V when the current is 0.0820 A. Determine its resistivity. **[3 marks]**

Answer / mark points: $R = V/I = 5.60/0.0820 = 68.3\ \Omega$. $A = \pi(0.360 \times 10^{-3}/2)^2 = 1.018 \times 10^{-7}\ m^2$. $\rho = RA/L = (68.3)(1.018 \times 10^{-7})/0.850 = 8.18 \times 10^{-6}\ \Omega\ m$.
Teacher prompt / common error: Use V/I to find the sample resistance, then rearrange the resistivity relation.

8. A technician claims that a longer piece of the same wire has a larger resistivity because it has a larger resistance. Explain the error in this claim. **[2 marks]**

Answer / mark points: Resistance depends on the sample dimensions as well as the material. Resistivity is a property of the material at a stated temperature; making the same wire longer increases R but does not change ρ.
Teacher prompt / common error: State that resistivity depends on material and temperature, not sample dimensions.

9. A design wire has length 2.4L and diameter 1.5d compared with a reference wire of length L and diameter d. Both use the same material. Determine the ratio $R_{design}/R_{reference}$. **[2 marks]**

Answer / mark points: $R_{design}/R_{reference} = 2.4/(1.5^2) = 1.07$. The design wire has about 7% greater resistance.
Teacher prompt / common error: Diameter is squared through the circular area.

4. Temperature and panel resistance

10. Describe how increasing temperature affects the resistivity of a metal and of a semiconductor. Use particle behaviour to explain one of these trends. [2 marks]

Answer / mark points: For a metal, resistivity increases as temperature rises because stronger lattice vibrations increase collisions with charge carriers. For a semiconductor, resistivity decreases because the number density of mobile charge carriers increases strongly with temperature.	
Teacher prompt / common error: For a metal, discuss collision frequency; for a semiconductor, discuss carrier number density.	

11. A wing panel contains two ribbon sections in series. Section P has length 3.4 m and width 3.0 mm. Section Q has length 2.6 m and width 2.0 mm. Both are 50 μm thick and have resistivity 1.10×10^{-6} Ω m. Calculate the total resistance and the current from a 48 V supply. [3 marks]

Answer / mark points: $R_P = 1.10 \times 10^{-6}(3.4)/[(3.0 \times 10^{-3})(50 \times 10^{-6})] = 24.9$ Ω. $R_Q = 1.10 \times 10^{-6}(2.6)/[(2.0 \times 10^{-3})(50 \times 10^{-6})] = 28.6$ Ω. $R_{total} = 53.5$ Ω and $I = 48/53.5 = 0.897$ A.	
Teacher prompt / common error: The same current passes through series sections, but their resistances must be calculated from their own widths and lengths.	

12. Calculate the power transferred by the panel in Question 11. [2 marks]

Answer / mark points: $P = IV = (0.897)(48) = 43.1$ W. $P = V^2/R$ gives the same result.	
Teacher prompt / common error: Use the operating current from Question 11, not a rounded design value.	

5. Parallel panels and design power

13. Two identical wing panels are connected in parallel across the 48 V supply. Calculate the total current and total power. [2 marks]

Answer / mark points: Each panel takes 0.897 A and transfers 43.1 W. In parallel, I_{total} = 1.79 A and P_{total} = 86.1 W.	
Teacher prompt / common error: Parallel branches share the p.d.; their currents and powers add.	

14. One panel develops an open circuit while the other remains connected to the ideal 48 V supply. State how the current and power in the working panel change, and determine the new total power. [2 marks]

Answer / mark points: The working panel still has 48 V across it, so its current and power remain 0.897 A and 43.1 W. The failed branch takes no current, so the new total power is 43.1 W.	
Teacher prompt / common error: An open branch does not change the p.d. across the remaining branch when the supply is ideal.	

15. A redesigned aircraft needs a total heater power of 120 W from two identical panels connected in parallel across 48 V. Each panel uses ribbon of resistivity 1.15×10^{-6} Ω m, width 2.6 mm and thickness 50 μm. Calculate the ribbon length required in each panel. [3 marks]

Answer / mark points: Each panel must transfer 60 W. $R_{panel} = V^2/P = 48^2/60 = 38.4$ Ω. $A = (2.6 \times 10^{-3})(50 \times 10^{-6}) = 1.30 \times 10^{-7}$ m^2. $L = RA/\rho = 38.4(1.30 \times 10^{-7})/(1.15 \times 10^{-6}) = 4.34$ m.	
Teacher prompt / common error: The 120 W is shared by two identical panels. Do not assign 120 W to each panel.	

6. Material choice

16. A further design requires a 5.0 m ribbon, width 2.5 mm, thickness 40 μm and resistance 50 Ω at 20 °C. Calculate the required resistivity and select the closest candidate from the table. [2 marks]

Candidate	Resistivity at 20 °C / Ω m	Change as temperature rises
A	1.00×10^{-6}	small increase
B	1.68×10^{-8}	increase
C	3.0×10^{-5}	decrease

Answer / mark points: $A = (2.5 \times 10^{-3})(40 \times 10^{-6}) = 1.00 \times 10^{-7}$ m^2. $\rho = RA/L = 50(1.00 \times 10^{-7})/5.0 = 1.00 \times 10^{-6}$ Ω m. Candidate A is the closest match.

Teacher prompt / common error: Choose by calculated resistivity. Temperature behaviour is additional design evidence, not a substitute for the calculation.

17. The heater is metallic and is connected to a constant-p.d. supply. Explain why its current and power are greatest just after switch-on and then decrease as the ribbon warms. [2 marks]

Answer / mark points: The ribbon is initially coolest, so its metallic resistivity and resistance are smallest. At fixed p.d., $I = V/R$ and $P = V^2/R$ are therefore greatest at switch-on. Heating raises ρ and R, so both current and power decrease.

Teacher prompt / common error: For constant p.d., increasing resistance reduces both I and V^2/R.

7. Operating data

18. During flight, one 5.0 m ribbon of width 2.5 mm and thickness 40 μm takes 0.840 A from 48.0 V. Calculate its operating resistivity. The 20 °C value is 1.00×10^{-6} Ω m. Determine the percentage increase and assess whether the result is consistent with a warm metallic ribbon. **[3 marks]**

Answer / mark points: R = V/I = 48.0/0.840 = 57.1 Ω. A = $(2.5 \times 10^{-3})(40 \times 10^{-6}) = 1.00 \times 10^{-7}$ m^2. ρ = RA/L = 1.14×10^{-6} Ω m. Increase = [(1.14 − 1.00)/1.00] × 100 = 14%. A positive increase is consistent with a metal operating above 20 °C.

Teacher prompt / common error: Use the rectangular cross-section. The direction of the change matters when judging a metal.

Language and method check

A sample has resistance; a material has resistivity at a stated temperature.
For a metal, resistivity increases as temperature increases; do not say that resistance 'gets hotter'.
When diameter changes, cross-sectional area changes with diameter squared.