

Resistance, Kirchhoff's rules and steady-state RC circuits

AP Physics 2 (algebra-based) · Worksheet answers

Each answer shows the formula, the substitution and the final result in bold. Compare your method as well as your numbers, because AP scoring rewards a clear line of reasoning even when the arithmetic slips.

Level: AP Physics 2 (algebra-based) · **Curriculum:** AP P2 Unit 11

Problem 1 Lamp resistance

1. $R = V/I = 4.5 / 0.30 = \mathbf{15\ \Omega}$.
2. $P = IV = 0.30 \times 4.5 = \mathbf{1.4\ W}$ (1.35 W).

Problem 2 Wire dimensions

1. $\mathbf{\Omega \cdot m}$ (ohm metre).
2. R is proportional to L, so doubling the length **doubles R**.
3. A is proportional to d^2 , so doubling d makes A four times larger and R **four times smaller**.

Problem 3 Three in series

1. $R_{eq} = 10 + 22 + 33 = \mathbf{65\ \Omega}$.
2. $I = V/R = 13 / 65 = \mathbf{0.20\ A}$.

Problem 4 Two in parallel

1. $1/R = 1/20 + 1/30 = 5/60$, so $R = \mathbf{12\ \Omega}$.
2. $I = 6.0 / 12 = \mathbf{0.50\ A}$ (0.30 A + 0.20 A through the two branches).

Problem 5 Heating element

1. $0.20\ \text{mm}^2 = 0.20 \times 10^{-6}\ \text{m}^2 = \mathbf{2.0 \times 10^{-7}\ m^2}$.
2. $R = \rho L/A = (1.1 \times 10^{-6})(2.0) / (2.0 \times 10^{-7}) = \mathbf{11\ \Omega}$.
3. $I = 5.5 / 11 = \mathbf{0.50\ A}$.

Problem 6 Junction currents

1. Current in = $3.0 + 2.0 = 5.0$ A. Out: $1.2 + I = 5.0$, so $I = \mathbf{3.8\text{ A}}$.
2. **Conservation of charge.**

Problem 7 Long wait

1. A fully charged capacitor blocks current: **0 A**.
2. $V = IR = \mathbf{0\text{ V}}$.
3. The battery emf is shared only by the capacitor, so its voltage equals the **battery emf**.

Problem 8 Charge and energy

1. $Q = CV = (220 \times 10^{-6})(9.0) = \mathbf{2.0 \times 10^{-3}\text{ C}}$ (1.98 mC).
2. $U = \frac{1}{2}CV^2 = 0.5 \times 220 \times 10^{-6} \times 81 = \mathbf{8.9 \times 10^{-3}\text{ J}}$.

Problem 9 Series-parallel network

1. $1/R_p = 1/6.0 + 1/3.0 = 3/6.0$, so $R_p = 2.0\ \Omega$. $R_{eq} = 8.0 + 2.0 = \mathbf{10\ \Omega}$.
2. $I = 15 / 10 = \mathbf{1.5\text{ A}}$.
3. V across the pair = $1.5 \times 2.0 = 3.0$ V, so $I = 3.0 / 6.0 = \mathbf{0.50\text{ A}}$.

Problem 10 Series or parallel lamps

1. Series: $R = 24\ \Omega$, $I = 0.25$ A, $P = IV = 0.25 \times 6.0 = \mathbf{1.5\text{ W}}$.
2. Parallel: $R = 6.0\ \Omega$, $I = 1.0$ A, $P = 6.0 \times 1.0 = \mathbf{6.0\text{ W}}$.
3. Each lamp gets 6.0 V in parallel (3.0 W each) but only 3.0 V in series (0.75 W each), so **parallel is brighter**.

Problem 11 Three bulbs

1. A carries the whole battery current I . B and C share it, so each carries $I/2$. Power is I^2R , so **A is brightest** and **B and C are equally dim**.
2. With C removed, the total resistance rises from $1.5R$ to $2R$. The current in A falls from $\varepsilon/1.5R$ to $\varepsilon/2R$, so **A dims**. The current in B rises from $\varepsilon/3R$ to $\varepsilon/2R$, because it no longer shares, so **B brightens**.

Problem 12 Length and resistance data

1. $R/L = 4.87 / 0.80 = \mathbf{6.1 \, \Omega/m}$.
2. $R/L = \rho/A$, so $\rho = (R/L)A = 6.09 \times 8.0 \times 10^{-8} = \mathbf{4.9 \times 10^{-7} \, \Omega \cdot m}$.

Problem 13 Aluminium cable

1. $A = \pi(0.225 \times 10^{-3})^2 = \mathbf{1.59 \times 10^{-7} \, m^2}$.
2. $R = (2.8 \times 10^{-8})(120) / (1.59 \times 10^{-7}) = \mathbf{21 \, \Omega}$.
3. $I = 12 / 21.1 = \mathbf{0.57 \, A}$.

Problem 14 Battery with internal resistance

1. $I = \mathcal{E}/(R + r) = 9.0 / 4.5 = \mathbf{2.0 \, A}$.
2. $V = \mathcal{E} - Ir = 9.0 - 2.0 \times 0.50 = \mathbf{8.0 \, V}$.
3. $P = I^2 r = 4.0 \times 0.50 = \mathbf{2.0 \, W}$.

Problem 15 Two batteries

1. $I_3 = I_1 + I_2$.
2. Loop 1: $9.0 - 1.0I_1 - 2.0I_3 = 0$. Loop 2: $3.0 - 1.0I_2 - 2.0I_3 = 0$.
3. Substituting I_3 : $3I_1 + 2I_2 = 9.0$ and $2I_1 + 3I_2 = 3.0$. Solving gives $I_1 = \mathbf{4.2 \, A}$, $I_2 = \mathbf{-1.8 \, A}$, $I_3 = \mathbf{2.4 \, A}$. The negative sign means the real current in the right branch flows downward through the 3.0 V battery, so that battery is being charged.

Problem 16 Designing a heater coil

1. $A = \pi(0.20 \times 10^{-3})^2 = \mathbf{1.26 \times 10^{-7} \, m^2}$.
2. $L = RA/\rho = 24 \times 1.26 \times 10^{-7} / 1.1 \times 10^{-6} = \mathbf{2.7 \, m}$.
3. $P = V^2/R = 240^2 / 24 = \mathbf{2400 \, W}$.

Problem 17 Capacitor in a network

1. At first the uncharged capacitor acts like a wire, so R_2 is in parallel with R_3 : $300 \times 100 / 400 = 75 \, \Omega$. Total $175 \, \Omega$, $I = 20 / 175 = \mathbf{0.11 \, A}$.
2. Voltage across the pair $= 0.1143 \times 75 = 8.57 \, V$, so $I_3 = 8.57 / 100 = \mathbf{0.086 \, A}$.
3. After a long time the capacitor branch carries no current, so $I = 20 / 400 = 0.050 \, A$. V across $R_2 = 15 \, V$, and R_3 has no drop, so $V_C = 15 \, V$. $Q = CV = 10 \times 10^{-6} \times 15 = \mathbf{1.5 \times 10^{-4} \, C}$.

Problem 18 Reading a charging graph

1. The curve levels at **6.0 V**, the battery emf.
2. 63 % of 6.0 V is 3.8 V, reached at **about 20 s**, which is τ .
3. $R = \tau/C = 20 / (1000 \times 10^{-6}) = \mathbf{2.0 \times 10^4 \Omega}$.
4. At $t = 0$ the capacitor acts like a wire: $I = 6.0 / 20\,000 = \mathbf{3.0 \times 10^{-4} A}$.

Problem 19 Spot the errors

1. The student added the resistor drops to the battery emf. Crossing a resistor along the current is a drop, so $12 - 2I - 4I = 0$ and $I = \mathbf{+2.0 A}$.
2. Resistors in parallel have a smaller total than either one: $1/R = 1/10 + 1/10$, so $R = \mathbf{5.0 \Omega}$. The student added them as if they were in series.

Problem 20 Dimming lamp

1. $I = 6.0 / (5.0 + 1.0) = 1.0 \text{ A}$. $P = I^2 R = \mathbf{5.0 W}$.
2. Parallel lamps: 2.5Ω . $I = 6.0 / 3.5 = 1.71 \text{ A}$. Terminal voltage = $6.0 - 1.71 \times 1.0 = \mathbf{4.3 V}$. Each lamp: $P = V^2/R = 4.29^2 / 5.0 = \mathbf{3.7 W}$.
3. The extra current causes a larger drop across the internal resistance, so the voltage across each lamp falls from 5.0 V to 4.3 V and the lamp dims.