Year 13 Science: Capacitors

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Two parallel plates, each of area 0.0100 m², are 0.200 mm apart in air. Find the capacitance.

2. Find the total capacitance of 6.0 µF and 3.0 µF in series, and in parallel.

3. How much energy does a 10 µF capacitor store at 12 V?

4. A 4.7 mF capacitor discharges through a 1.0 kΩ resistor. Find the time constant and roughly how long it takes to discharge fully.

Exam-style question: a camera flash

A camera flash stores energy in a 220 µF capacitor charged to 330 V. After each flash, it is recharged from a 330 V supply through a 1.50 kΩ resistor.

5. Calculate the charge and energy stored when the capacitor is full.

6. Calculate the time constant, the starting recharge current, and the current after one time constant.

7. Explain why the recharge current is largest at the start and falls to zero.

8. A designer suggests two 220 µF capacitors charged from the same 330 V supply. Explain, with calculations, how much energy they store connected in parallel compared with in series across 330 V.

Fix the mistake

9. Correct this statement: "6.0 µF and 3.0 µF in series make 9.0 µF."

10. Correct this statement: "$\tau = RC = 2.20 \times 470 = 1034$ s, with kΩ and µF left as they are."

11. Correct this statement: "After one time constant the capacitor is half charged."

12. Correct this statement: "When the capacitor is fully charged the current is at its maximum because the most charge is stored."

Answer key (for parents and tutors)

1. Two parallel plates, each of area 0.0100 m², are 0.200 mm apart in air. Find the capacitance.
   $C = \varepsilon_0 A \div d = 8.85 \times 10^{-12} \times 0.0100 \div 2.00 \times 10^{-4} = 4.43 \times 10^{-10}$ F (443 pF).

2. Find the total capacitance of 6.0 µF and 3.0 µF in series, and in parallel.
   Series: $1 \div C = 1 \div 6.0 + 1 \div 3.0 = 0.50$, so C = 2.0 µF; parallel: 6.0 + 3.0 = 9.0 µF.

3. How much energy does a 10 µF capacitor store at 12 V?
   $E = \frac{1}{2}CV^2 = \frac{1}{2} \times 10 \times 10^{-6} \times 12^2 = 7.2 \times 10^{-4}$ J (0.72 mJ).

4. A 4.7 mF capacitor discharges through a 1.0 kΩ resistor. Find the time constant and roughly how long it takes to discharge fully.
   $\tau = RC = 1000 \times 4.7 \times 10^{-3} = 4.7$ s; it is effectively discharged after about $5\tau = 24$ s.

5. Calculate the charge and energy stored when the capacitor is full.
   $Q = CV = 220 \times 10^{-6} \times 330 = 0.0726$ C; $E = \frac{1}{2}CV^2 = \frac{1}{2} \times 220 \times 10^{-6} \times 330^2 = 12.0$ J (Achieved).

6. Calculate the time constant, the starting recharge current, and the current after one time constant.
   $\tau = RC = 1500 \times 220 \times 10^{-6} = 0.330$ s; $I_0 = 330 \div 1500 = 0.220$ A; after one τ, $I = 0.368 \times 0.220 = 0.0809$ A (Merit for all three).

7. Explain why the recharge current is largest at the start and falls to zero.
   At the start the capacitor is empty, so it has no voltage across it and the full 330 V is across the resistor, giving the biggest current. As charge builds up, the capacitor's voltage $V = Q \div C$ rises and opposes the supply, so the voltage across the resistor, $\varepsilon - V_C$, falls, and so does the current. When V_C reaches 330 V the resistor has no voltage and the current is zero (Excellence links the charge, the capacitor voltage and the resistor current).

8. A designer suggests two 220 µF capacitors charged from the same 330 V supply. Explain, with calculations, how much energy they store connected in parallel compared with in series across 330 V.
   In parallel the total is 440 µF at 330 V: $E = \frac{1}{2} \times 440 \times 10^{-6} \times 330^2 = 24.0$ J, double one capacitor. In series the total is 110 µF across 330 V, so each has only 165 V: $E = \frac{1}{2} \times 110 \times 10^{-6} \times 330^2 = 5.99$ J, half of one capacitor. Parallel stores four times as much as series because the voltage on each capacitor is not shared and E depends on V^2 (Excellence for the comparison with reasons).

9. Correct this statement: "6.0 µF and 3.0 µF in series make 9.0 µF."
   In series the reciprocals add: $1 \div C = 1 \div 6.0 + 1 \div 3.0$, so C = 2.0 µF; 9.0 µF is the parallel total.

10. Correct this statement: "τ = RC = 2.20 × 470 = 1034 s, with kΩ and µF left as they are."
    Use ohms and farads: $\tau = 2200\ \Omega \times 470 \times 10^{-6}$ F = 1.03 s.

11. Correct this statement: "After one time constant the capacitor is half charged."
    After one τ it reaches 63% of full charge; it is half charged at about 0.69τ.

12. Correct this statement: "When the capacitor is fully charged the current is at its maximum because the most charge is stored."
    Fully charged, the capacitor's voltage equals the supply's, the resistor has no voltage and the current is zero.