

Capacitors, energy storage and dielectrics

AP Physics C (Mechanics and E&M, calculus-based) · Test answers (mark scheme)

Award marks as shown. Accept results within rounding, give full credit to a correct method carried through from an earlier slip, and take off a mark once for a missing unit.

Level: AP Physics C (Mechanics and E&M, calculus-based) · **Curriculum:** AP PC:E&M Unit 10

Question 1 Capacitance and charge (2 marks)

Capacitance is the ratio $C = Q/\Delta V$ of the charge on one conductor to the potential difference between them. Since ΔV is proportional to Q for a fixed geometry, the ratio is constant and depends only on shape and material.

Marking: 1 mark for the definition; 1 mark for the proportionality argument.

Question 2 Parallel plate capacitor (3 marks)

$C = \epsilon_0 A/d = (8.85 \times 10^{-12})(0.050)/(1.0 \times 10^{-3}) = \mathbf{4.4 \times 10^{-10} \text{ F}}$. $Q = C\Delta V = (4.43 \times 10^{-10})(9.0) = \mathbf{4.0 \times 10^{-9} \text{ C}}$.

Marking: 1 mark for the formula and substitution; 1 mark for C; 1 mark for Q.

Question 3 Energy stored (3 marks)

$U = \frac{1}{2}C\Delta V^2 = \frac{1}{2}(220 \times 10^{-6})(900) = \mathbf{0.099 \text{ J}}$. $P = U/t = 0.099/(5.0 \times 10^{-4}) = \mathbf{2.0 \times 10^2 \text{ W}}$.

Marking: 1 mark for the formula; 1 mark for U; 1 mark for P.

Question 4 Dielectric inserted (3 marks)

$Q = 5.0 \text{ nC}$ is fixed. $V = 50/2.5 = \mathbf{20 \text{ V}}$, and $U = \frac{1}{2}QV = \frac{1}{2}(5.0 \times 10^{-9})(20) = \mathbf{5.0 \times 10^{-8} \text{ J}}$.

Marking: 1 mark for Q constant; 1 mark for V; 1 mark for U.

Question 5 Why the field falls (2 marks)

The dielectric polarises: its surface facing the positive plate gains negative bound charge and the other face gains positive bound charge. These oppose the field of the plates, so the net field and potential difference fall.

Marking: 1 mark for polarisation producing bound charge; 1 mark for the opposing field reducing E.

Question 6 Coaxial capacitor (3 marks)

$$C = 2\pi\epsilon_0 L / \ln(b/a) = (5.56 \times 10^{-11})(2.0) / \ln 4 = 1.112 \times 10^{-10} / 1.386 = \mathbf{8.0 \times 10^{-11} \text{ F}}.$$

Marking: 1 mark for the formula; 1 mark for $\ln 4$; 1 mark for the value with unit.

Question 7 Energy density (2 marks)

$$u = \frac{1}{2}\epsilon_0 E^2 = \frac{1}{2}(8.85 \times 10^{-12})(1.2 \times 10^4)^2 = \mathbf{6.4 \times 10^{-4} \text{ J/m}^3}.$$

Marking: 1 mark for the formula; 1 mark for the answer with unit.

Question 8 Series pair (2 marks)

a. $1/C = 1/6.0 + 1/3.0 = 1/2.0$, so **C = 2.0 μF** .

b. $Q = (2.0 \mu\text{F})(9.0 \text{ V}) = 18 \mu\text{C}$, so $V = 18/3.0 = \mathbf{6.0 \text{ V}}$.

Marking: 1 mark for each part.