Name: _____

AP Physics C: E&M

Unit 3 Complete Review

Conductors and Capacitors

---

1. A hollow conducting sphere is in electrostatic equilibrium. Which of the following statements is always true?

   (A) The electric field is the same at all points outside the sphere

   (B) The electric potential is the same at all points on the sphere

   (C) The charge density is the same everywhere on the sphere

   (D) The electric field inside the conductor is NOT zero

2. Two conducting objects carry the same total charge. Object I is nearly spherical, while Object II has several sharp points.

   Compared to Object I, the charge density near the sharp points of Object II is

   (A) smaller

   (B) the same

   (C) greater

   (D) impossible to determine

3. A student claims that because a conductor is an equipotential surface, the electric field everywhere on its surface must be zero.

   Which of the following best evaluates the student's claim?

   (A) Correct, because equal potential implies zero electric field everywhere

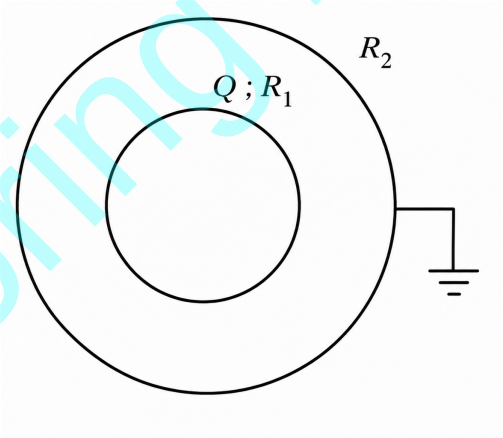
   (B) Correct, because all charge resides on the surface

   (C) Incorrect, because the electric field can be perpendicular on its surface

   (D) Incorrect, because conductors are not equipotential surfaces

4. Two concentric conducting spherical shells are shown. The inner shell has radius R_1 and carries a charge $+Q$. The outer shell has radius R_2 and is connected to ground, as shown.

   After electrostatic equilibrium is established, what is the net charge on the outer conducting shell?



   (A) $+Q$

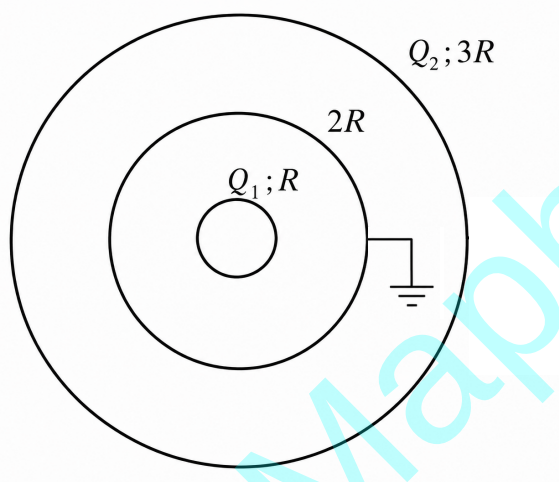
   (B) $-Q$

   (C) 0

   (D) $-2Q$

5. Three concentric conducting spherical shells have radii R, $2R$, and $3R$, as shown. The innermost shell carries charge Q_1, and the outermost shell carries charge Q_2. The shell of radius $2R$ is connected to ground.

   After electrostatic equilibrium is established, what is the net charge on the shell of radius $2R$?



(A) $-Q_1$

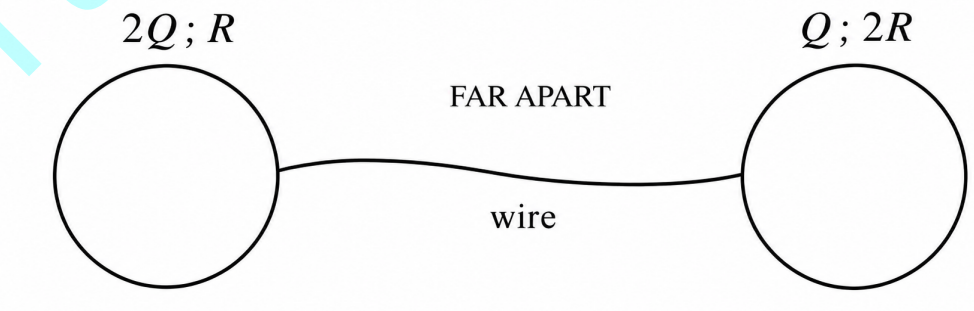
(B) $-Q_2$

(C) $-\frac{Q_1}{2} - \frac{Q_2}{3}$

(D) $-Q_1 - \frac{2Q_2}{3}$

6. Two conducting spheres are placed very far apart and connected by a thin conducting wire.The sphere on the left has radius R and initially carries charge $2Q$ .The sphere on the right has radius $2R$ and initially carries charge Q

   After electrostatic equilibrium is established, what is the final charge on the sphere of radius $2R$?



(A) Q

(B) $\frac{3Q}{2}$

(C) $2Q$

(D) $\frac{5Q}{2}$

7. A parallel-plate capacitor has a capacitance C_0. A second parallel-plate capacitor is constructed with plates that have twice the area and twice the separation of the first capacitor.

   What is the capacitance of the second capacitor?

   (A) $\frac{1}{4}C_0$

   (B) $\frac{1}{2}C_0$

   (C) C_0

   (D) $2C_0$

8. Three $12\,\mu$F capacitors are connected in series. What is the equivalent capacitance of the combination?

   (A) $4\,\mu$F

   (B) $2\,\mu$F

   (C) $9\,\mu$F

   (D) $18\,\mu$F

9. Two $4\,\mu$F capacitors are connected in series to a $12\,$V battery. What is the energy stored in each capacitor?

   (A) $144\,\mu$J

   (B) $4\,\mu$J

   (C) $36\,\mu$J

   (D) $72\,\mu$J

10. An isolated capacitor with air between its plates has a potential difference V_0 and a charge Q_0. The space between the plates is then completely filled with a dielectric material. After the dielectric is inserted, the potential difference is V and the charge is Q.

    Which of the following relationships is correct?

    (A) $Q = Q_0$ and $V > V_0$
    (B) $Q = Q_0$ and $V < V_0$
    (C) $Q < Q_0$ and $V < V_0$
    (D) $Q > Q_0$ and $V > V_0$

11. Which of the following quantities, together with fundamental constants only, can be used to determine the magnitude of the electric field between the plates of a parallel-plate capacitor whose plate dimensions and separation are unknown?

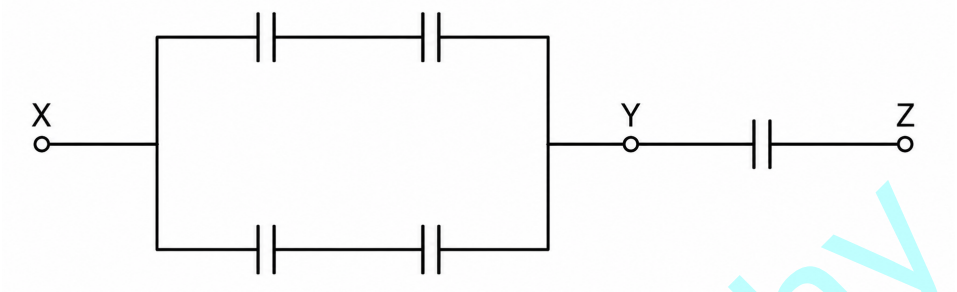
    (A) The electric flux between the plates
    (B) The total charge on either plate
    (C) The potential difference between the plates
    (D) The surface charge density on either plate

12. Two identical parallel-plate capacitors are connected in series.

    Which of the following statements about the equivalent capacitance is correct?

    (A) It depends on the charge stored on each capacitor
    (B) It depends on the potential difference across the combination
    (C) It is larger than the capacitance of either capacitor
    (D) It is smaller than the capacitance of either capacitor

13. Five identical $4\,\mu$F capacitors are connected as shown. Points X and Z are connected across a 12 V battery.



(i) What is the equivalent capacitance between points X and Z?

(A) $2\,\mu$F
(B) $4\,\mu$F
(C) $6\,\mu$F
(D) $12\,\mu$F

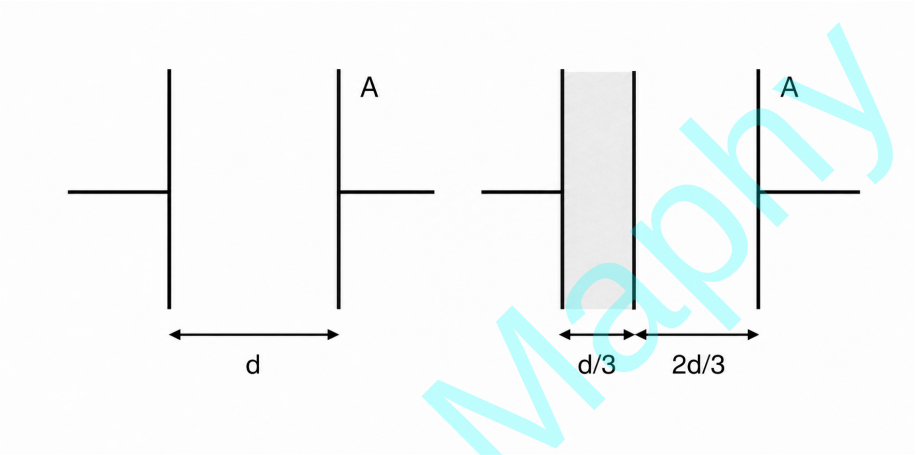
(ii) What is the potential difference between points Y and Z?

(A) 4 V
(B) 3 V
(C) 6 V
(D) 9 V

14. A parallel-plate capacitor has capacitance C_0, plate area A, and plate separation d.

A second capacitor has the same plate area and separation. A dielectric of dielectric constant k completely covers the plate area but fills only one-third of the separation between the plates.

What is the capacitance of the second capacitor in terms of C_0?



(A) $\dfrac{3kC_0}{2k+1}$

(B) $\dfrac{3C_0}{2k}$

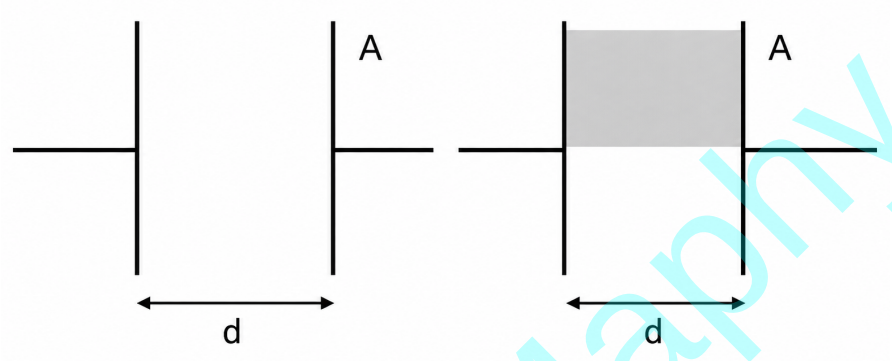
(C) $\dfrac{3C_0}{k}$

(D) $\dfrac{2C_0}{2k+1}$

15. A parallel-plate capacitor has capacitance C_0, plate area A, and plate separation d.

A second capacitor has the same plate area and separation. A dielectric of dielectric constant k fills the entire separation between the plates but covers only one-half of the area of each plate.

What is the capacitance of the second capacitor in terms of C_0?



(A) $\frac{(k+1)C_0}{3}$

(B) $\frac{kC_0}{3}$

(C) $\frac{kC_0}{2}$

(D) $\frac{(k+1)C_0}{2}$

16. A parallel-plate capacitor has charge $+Q$ on one plate and charge $-Q$ on the other. The plates have area A, are separated by a distance d, and the space between them is vacuum. A proton of charge $+e$ is released from rest at the surface of the positively charged plate and moves toward the negatively charged plate.

What is the kinetic energy of the proton when it reaches the opposite plate?

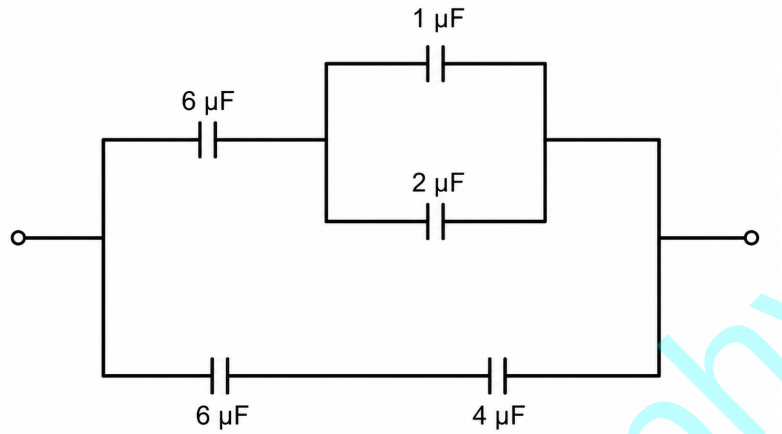
(A) $\frac{eQd}{\varepsilon_0 A}$

(B) $\frac{\varepsilon_0 Qd}{eA}$

(C) $\frac{\varepsilon_0 QA}{d}$

(D) $\frac{\varepsilon_0 Qe}{dA}$

17. What is the equivalent capacitance of the circuit shown above?



(A) $4.4\,\mu\text{F}$

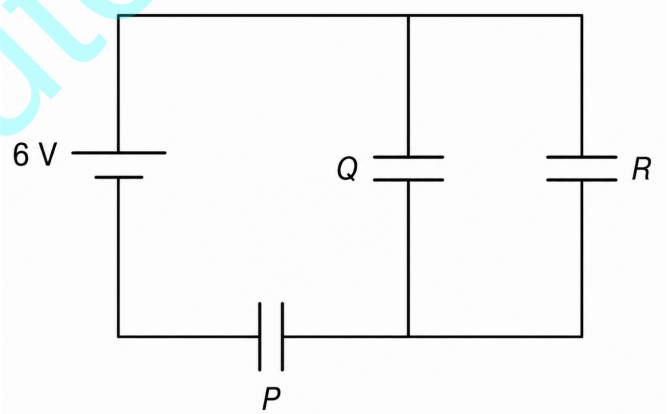
(B) $3.0\,\mu\text{F}$

(C) $4.0\,\mu\text{F}$

(D) $8.0\,\mu\text{F}$

18. Three identical $425\,\mu\text{F}$ capacitors P, Q, and R are connected to a $6.0\,\text{V}$ battery as shown.

(i) What is the equivalent capacitance of the combination?



(A) $\frac{850}{3}\,\mu\text{F}$

(B) $425\,\mu\text{F}$

(C) $850\,\mu\text{F}$

(D) $\frac{425}{3}\,\mu\text{F}$

(ii) What is the charge stored on capacitor P?

(A) $850\,\mu\text{C}$

(B) $1700\,\mu\text{C}$

(C) $2550\,\mu\text{C}$

(D) $425\,\mu\text{C}$

(iii) What is the charge stored on capacitor Q?

(A) $1700\,\mu\text{C}$

(B) $2550\,\mu\text{C}$

(C) $850\,\mu\text{C}$

(D) $425\,\mu\text{C}$

19. A parallel-plate capacitor is connected to a battery and charged. The battery is then disconnected, and a dielectric of dielectric constant k is inserted completely between the plates.

Which of the following correctly describes the new values of the charge Q, capacitance C, electric field magnitude E, potential difference V, and stored energy U compared with their initial values?

Option	Q	C	E	V	U
(A)	same	kC	E/k	V/k	U/k
(B)	kQ	kC	E/k	V	kU
(C)	same	kC	kE	V/k	kU
(D)	same	kC	E	V/k	U/k

20. A parallel-plate capacitor is connected to an ideal battery. A dielectric of dielectric constant k is then slowly inserted until it completely fills the space between the plates while the capacitor remains connected to the battery.

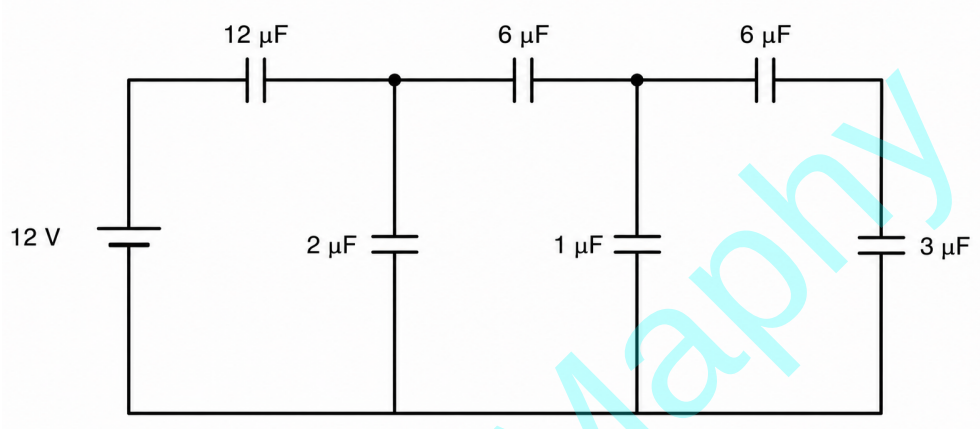
Which of the following correctly describes the new values of the charge Q, capacitance C, electric field magnitude E, potential difference V, and stored energy U compared with their initial values?

Option	Q	C	E	V	U
(A)	Q	kC	E/k	V/k	kU
(B)	kQ	kC	E	V	kU
(C)	Q	kC	E	V/k	kU
(D)	kQ	kC	kE	V	U/k

FRQ

21. Part I

A capacitor network is connected to a 12 V battery as shown. The circuit has been connected to the battery for a long time and has reached electrostatic equilibrium.



(a) Determine the equivalent capacitance of the entire network.

(b) Determine the charge stored on the 12 μF capacitor.

(c) Determine the potential difference across the 2 μF capacitor.

(d) Without performing any calculations, compare the energy stored in the two $6\,\mu$F capacitors.

_____ $U_{\text{left } 6\,\mu\text{F}} < U_{\text{right } 6\,\mu\text{F}}$

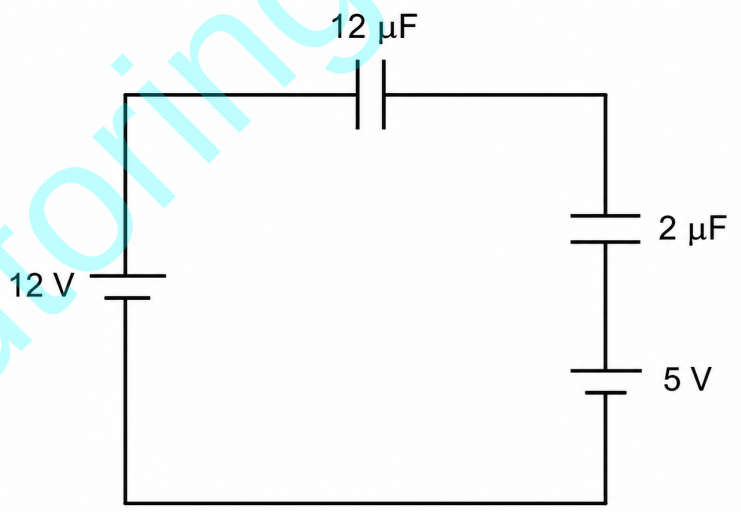
_____ $U_{\text{left } 6\,\mu\text{F}} > U_{\text{right } 6\,\mu\text{F}}$

_____ $U_{\text{left } 6\,\mu\text{F}} = U_{\text{right } 6\,\mu\text{F}}$

Provide a brief justification.

Part II

The original capacitors are disconnected from the battery. A new circuit is constructed using the $12\,\mu$F capacitor and the $2\,\mu$F capacitor, as shown above.



(e) Determine the charge stored on the $2\,\mu$F capacitor.