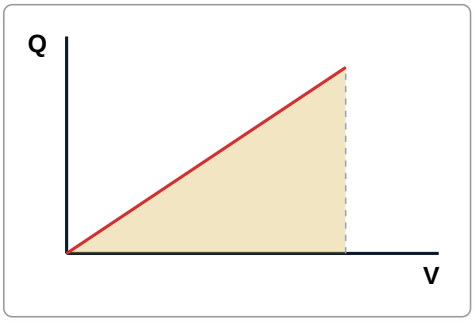
One Mentor Academy

BPhO Round 0 - Capacitance & Energy Stored

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Instructions: Attempt all 30 multiple-choice questions. Select the single best answer for each. Questions range from A-Level standard to challenging BPhO problem-solving extensions. Assume all ideal components unless otherwise stated. Note: Time-dependent RC charging/discharging calculations are explicitly excluded.

1. The graph below shows the relationship between the charge Q stored on an ideal capacitor and the potential difference V across its plates. What do the gradient of the line and the shaded area under the line represent, respectively?



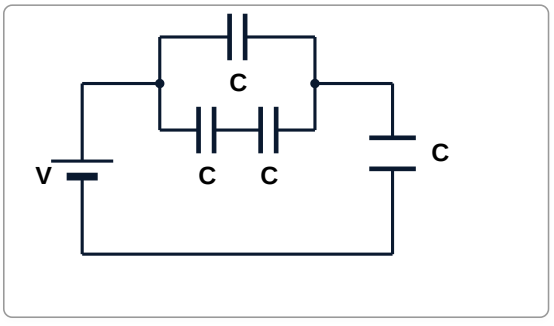
A Gradient = Capacitance, Area = Energy Stored

B Gradient = Energy Stored, Area = Capacitance

C Gradient = $1/\text{Capacitance}$, Area = Energy Stored

D Gradient = Capacitance, Area = Power

2. Four identical capacitors, each of capacitance C, are connected in the mixed network shown below to a DC cell of voltage V. What is the equivalent capacitance of this entire network?



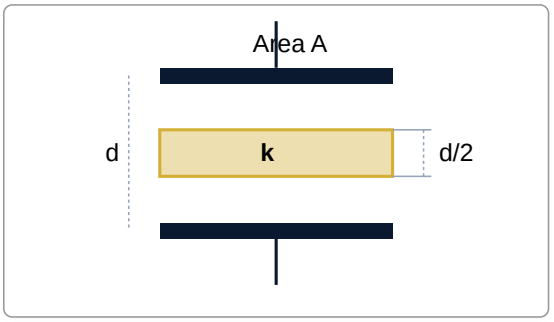
A $\frac{2}{3}C$

B $\frac{3}{5}C$

C $\frac{5}{3}C$

D $\frac{3}{2}C$

3. An air-filled parallel plate capacitor has capacitance C_0, plate area A, and separation d. A dielectric slab of constant k and thickness $d/2$ is inserted exactly halfway between the plates, as shown. What is the new capacitance of the system?



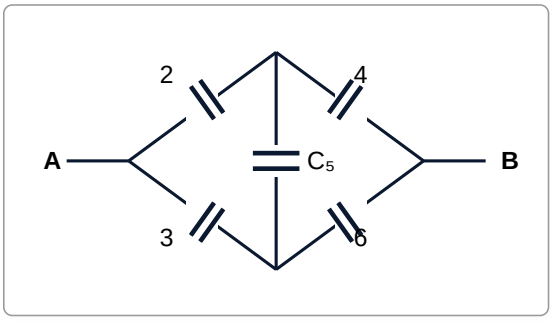
A $C_0\left(\frac{2k}{k+1}\right)$

B $C_0\left(\frac{k+1}{2k}\right)$

C $C_0\left(\frac{k}{k+1}\right)$

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

4. A Wheatstone bridge circuit is constructed entirely of capacitors as shown. If the bridge is perfectly balanced, meaning no charge flows through the central capacitor C_5, what is the equivalent capacitance of the network between nodes A and B?



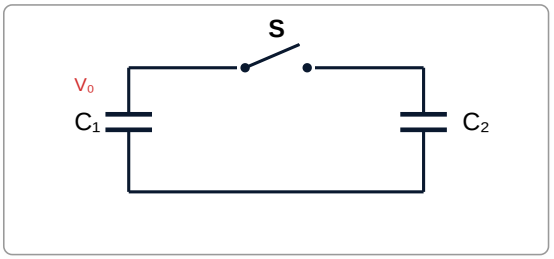
A $2.0\,\mu\text{F}$

B $3.3\,\mu\text{F}$

C $4.2\,\mu\text{F}$

D $15.0\,\mu\text{F}$

5. Capacitor C_1 is initially charged to a potential difference V_0. Capacitor C_2 is initially uncharged. The switch S is then closed, allowing charge to share between them. What is the total energy dissipated (lost as heat/radiation) during this process?



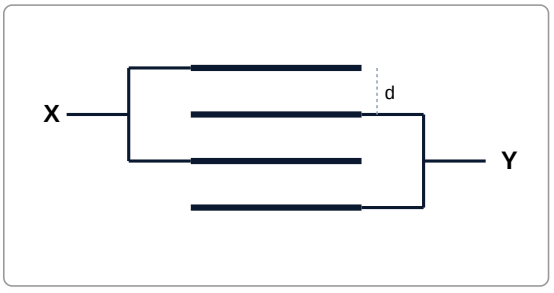
A $\frac{1}{2}(C_1 + C_2)V_0^2$

B $\frac{1}{2}\left(\frac{C_1C_2}{C_1+C_2}\right)V_0^2$

C $\frac{1}{2}\left(\frac{C_1^2}{C_1+C_2}\right)V_0^2$

D Zero (Energy is conserved)

6. A multi-plate capacitor consists of 4 identical parallel metal plates, each of area A, separated by equal distances d in air. The plates are connected alternately to terminals X and Y as shown. What is the equivalent capacitance between X and Y?



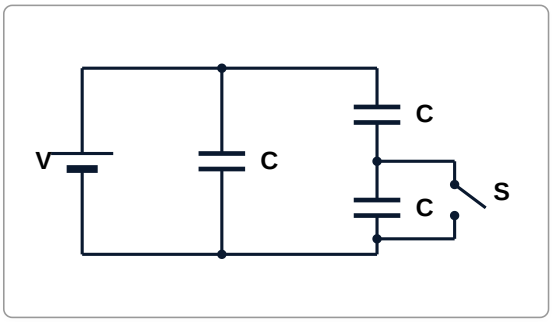
A $\frac{\epsilon_0 A}{d}$

B $\frac{3\epsilon_0 A}{d}$

C $\frac{4\epsilon_0 A}{d}$

D $\frac{\epsilon_0 A}{3d}$

7. In the circuit below, three identical capacitors each of capacitance C are connected to a cell of voltage V. When the switch S is closed, what is the change in the total energy stored in the network?



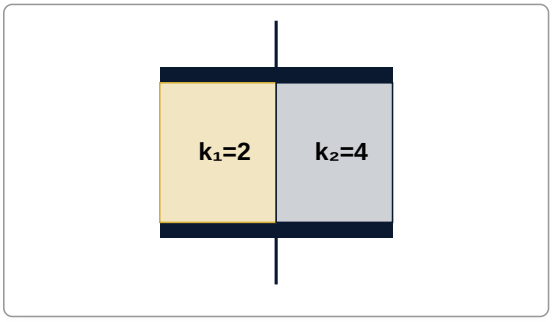
A Increases by $\frac{1}{4}CV^2$

B Increases by $\frac{1}{2}CV^2$

C Decreases by $\frac{1}{4}CV^2$

D Remains unchanged

8. An air-filled parallel plate capacitor has capacitance C_0. Two different dielectric materials, with dielectric constants $k_1 = 2$ and $k_2 = 4$, are inserted such that each completely fills exactly one half of the area between the plates, as shown. What is the new total capacitance?



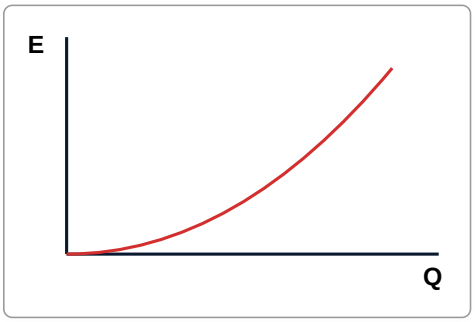
A $3C_0$

B $\frac{4}{3}C_0$

C $6C_0$

D $1.5C_0$

9. The graph depicts the energy E stored in a fixed capacitor as a function of the charge Q on its plates. What does the mathematical nature of this curve indicate about the capacitance?



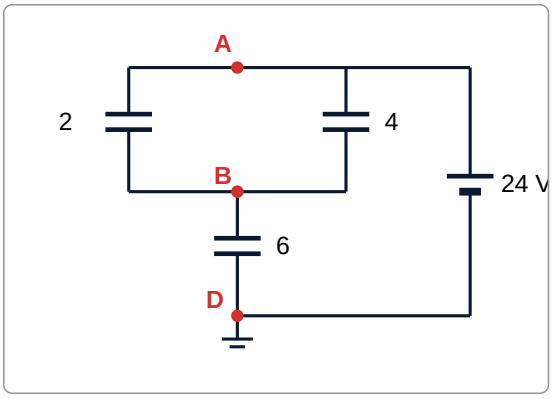
A $E \propto Q$ meaning C is constant.

B $E \propto Q^2$ meaning C is proportional to Q.

C $E \propto Q^2$ meaning C is constant and equals $\frac{1}{2 \times \text{gradient}}$.

D $E \propto Q^2$ and the constant of proportionality is $\frac{1}{2C}$.

10. In the circuit diagram below, a battery of $24\ \text{V}$ is connected across a network of three capacitors. What is the potential at node B if node D is grounded (0 V)?



A 6 V

B 12 V

C 16 V

D 18 V

11. An isolated parallel-plate capacitor holds a constant charge Q. If the separation between the plates is doubled by an external mechanical force, what happens to the energy stored in the capacitor?

A It remains constant.

B It halves.

C It doubles.

D It quadruples.

12. A parallel-plate capacitor remains connected to a constant voltage supply V. If the plate separation is doubled, what is the work done by the external agent moving the plates?

A $+\frac{1}{4}CV^2$

B $-\frac{1}{4}CV^2$

C $+\frac{1}{2}CV^2$

D Zero

13. A capacitor is charged and then isolated from the battery. A dielectric slab ($k > 1$) is inserted between the plates. Which of the following statements about the energy stored is correct?

A Energy increases because capacitance increases.

B Energy decreases, and the slab is pulled in by the electric field.

C Energy increases, and work must be done to push the slab in.

D Energy remains constant due to conservation of charge.

14. Eight identical spherical mercury drops, each charged to a potential V, coalesce to form a single large drop. Assuming charge is conserved and the drops are perfectly spherical, what is the potential of the new large drop?

A V

B $2V$

C $4V$

D $8V$

15. The capacitance of an isolated spherical conductor of radius R in a vacuum is given by $C = 4\pi\epsilon_0 R$. If the Earth is modeled as a conducting sphere of radius $\approx 6400\ \text{km}$, its approximate capacitance is:

A $711\ \mu\text{F}$

B $1.0\ \text{F}$

C $7.1\ \text{mF}$

D ∞

16. Two capacitors $C_1 = 2\ \mu\text{F}$ and $C_2 = 4\ \mu\text{F}$ are connected in series across a 12 V battery. What is the potential difference across the $2\ \mu\text{F}$ capacitor?

A 4 V

B 6 V

C 8 V

D 12 V

17. Three capacitors of capacitances $1\ \mu\text{F}$, $2\ \mu\text{F}$, and $3\ \mu\text{F}$ are connected in series. What is the equivalent capacitance of this combination?

A $6\ \mu\text{F}$

B $\frac{11}{6}\ \mu\text{F}$

C $\frac{6}{11}\ \mu\text{F}$

D $1\ \mu\text{F}$

18. Three capacitors of capacitances $1\ \mu\text{F}$, $2\ \mu\text{F}$, and $3\ \mu\text{F}$ are connected in parallel. What is the equivalent capacitance of this combination?

A $\frac{6}{11}\ \mu\text{F}$

B $\frac{11}{6}\ \mu\text{F}$

C $6\ \mu\text{F}$

D $3\ \mu\text{F}$

19. An air-filled capacitor stores an energy U_0 when connected to a battery. The battery is kept connected while a dielectric of constant $k = 3$ is inserted. What is the new energy stored?

A $U_0/9$

B $U_0/3$

C $3U_0$

D $9U_0$

20. In an ideal parallel-plate capacitor, the energy density (energy per unit volume) stored in the uniform electric field E is proportional to:

A E

B E^2

C $1/E$

D $1/E^2$

21. Two identical capacitors are first connected in series, and then in parallel, across the same DC voltage source. What is the ratio of the total energy stored in the series arrangement to that in the parallel arrangement?

A 1 : 1

B 1 : 2

C 1 : 4

D 4 : 1

22. Capacitor A has capacitance C and is charged to voltage V. Capacitor B has capacitance $2C$ and is uncharged. They are connected in parallel. What fraction of the initial energy is lost during charge sharing?

A 1/3

B 1/2

C 2/3

D 0

23. A 100 pF capacitor is charged to 50 V. It is then disconnected from the supply and connected in parallel to an unknown uncharged capacitor. The voltage across the combination drops to 20 V. What is the capacitance of the unknown capacitor?

A 40 pF

B 60 pF

C 150 pF

D 250 pF

24. The plates of an isolated parallel-plate capacitor carrying charge Q are pulled apart. The force required to pull them apart is:

A Proportional to the separation distance$x$.

B Inversely proportional to$x$.

C Inversely proportional tox^2.

D Constant, independent of$x$.

25. A variable capacitor in a tuning circuit has its capacitance changed from C to $3C$ while remaining connected to a battery of constant voltage V. The work done by the battery during this process is:

A CV^2

B $2CV^2$

C $\frac{1}{2}CV^2$

D $\frac{3}{2}CV^2$

26. If the area of the plates of a parallel plate capacitor is doubled and the separation between them is halved, the energy stored at a constant potential difference will:

A Remain unchanged

B Double

C Quadruple

D Increase by a factor of 8

27. A capacitor of capacitance C holds a charge Q. An identical uncharged capacitor is connected in series with it. What is the new total stored energy of the system?

A $\frac{Q^2}{4C}$

B $\frac{Q^2}{2C}$

C $\frac{Q^2}{C}$

D Trick question: charge cannot flow in an isolated series loop, so it remains $\frac{Q^2}{2C}$.

28. A flash lamp requires 10 J of energy to fire. It is powered by a $2000\ \mu\text{F}$ capacitor. To what minimum voltage must the capacitor be charged?

A 50 V

B 71 V

C 100 V

D 141 V

29. Two metal plates are separated by a distance d. The space is filled with two different dielectrics of equal thickness $d/2$ stacked in series (one on top of the other). If their dielectric constants are k_1 and k_2, the equivalent capacitance is proportional to:

A $k_1 + k_2$

B $\frac{k_1 k_2}{k_1 + k_2}$

C $\frac{k_1 + k_2}{2}$

D $\sqrt{k_1 k_2}$

30. A parallel-plate capacitor is charged and isolated. If a metal slab of thickness $d/3$ is inserted parallel to the plates, what happens to the capacitance?

A Increases by 50%

B Decreases by 33%

C Increases by 33%

D Becomes infinite

Answer Key

1. A	**2.** B	**3.** A	**4.** C	**5.** B
6. B	**7.** A	**8.** A	**9.** D	**10.** B
11. C	**12.** A	**13.** B	**14.** C	**15.** A
16. C	**17.** C	**18.** C	**19.** C	**20.** B
21. C	**22.** C	**23.** C	**24.** D	**25.** B
26. C	**27.** D	**28.** C	**29.** B	**30.** A