

**UNIT 8 TEST REVIEW****Electric Potential and Capacitance: Chapters 24-25**

\* In studying for your test, make sure to study this review sheet along with your quizzes and homework assignments.

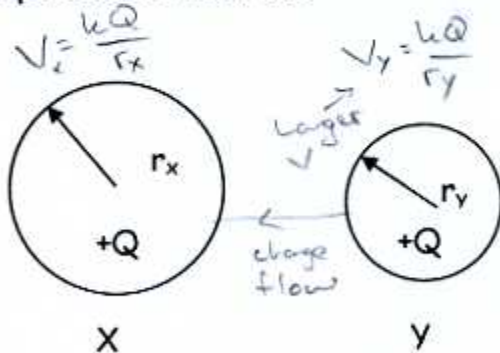
**Multiple Choice Review:** On this portion of the test, you will not be allowed to use your calculator or AP formula sheet. (You may, however, use your AP table of information.) Approximate  $g=10\text{m/s}^2$  for simplicity of calculations. No partial credit will be given.

- When two identical parallel-plate capacitors are connected in series, which of the following is true of the equivalent capacitance?
  - It depends on the charge of each capacitor.
  - It depends on the potential difference across both capacitors.
  - It is larger than the capacitance of each capacitor.
  - It is smaller than the capacitance of each capacitor. ← Because of inverse addition.
  - It is the same as the capacitance of each capacitor.

- A charge distribution creates an electric potential that varies along the x-axis as  $V(x) = 2x^2 - 5x$ . What is the x-component of the electric field at  $x=1$ ?
  - 3 V/m
  - 3 V/m
  - 1 V/m
  - 1 V/m
  - 0

$$E_x = -\frac{dV}{dx} = -(4x - 5) = -(4(1) - 5) = 1$$

- Two conducting spheres, X and Y, have the same positive charge  $+Q$ , but different radii ( $r_x > r_y$ ) as shown. The spheres are separated so that the distance between them is large compared with either radius. If a wire is connected between them, in which direction will current be directed in the wire?
  - From X to Y
  - From Y to X
  - There will be no current in the wire.
  - It cannot be determined without knowing the magnitude of  $Q$ .
  - It cannot be determined without knowing whether the spheres are solid or hollow.



Charge will flow so that they arrive @ same  $V$ .

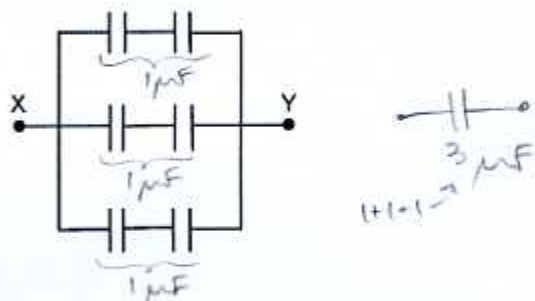
4. An air-gap capacitor with capacitance of  $C$  is connected across a battery with potential difference  $V$ , setting up an electric field of strength  $E$  and causing the capacitor to store charge  $Q$ . Then the capacitor is disconnected from the battery and a substance with dielectric constant 3 is inserted to fill the space between the plates. What are the values for capacitance, potential difference, electric field magnitude, and charge stored, after the dielectric is in place?

	<u>Capacitance</u>	<u>Pot. Diff.</u>	<u>E-Field</u>	<u>Charge Stored</u>
a.	$3C$	$3V$	$3E$	$3Q$
b.	$3C$	$V/3$	$E/3$	$3Q$
c.	$3C$	$V$	$E$	$3Q$
<b>d.</b>	$3C$	$V/3$	$E/3$	$Q$
e.	$C$	$V/3$	$E/3$	$Q$

Must store same charge, since there's nowhere for charges to go

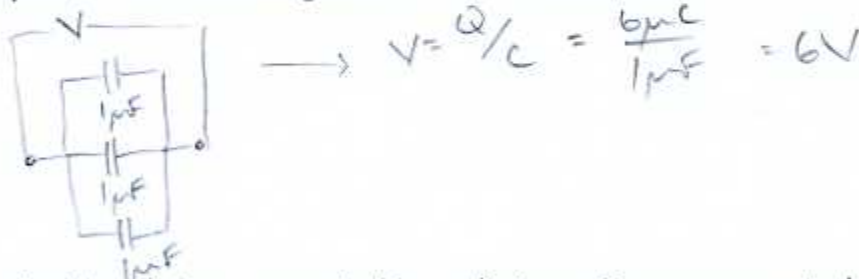
5. Each capacitor in the system shown below has a capacitance of  $2\mu\text{F}$ . The equivalent capacitance of the system of capacitors is closest to which of the following?

- a.  $2/3\mu\text{F}$   
 b.  $4/3\mu\text{F}$   
**c.  $3\mu\text{F}$**   
 d.  $6\mu\text{F}$   
 e.  $12\mu\text{F}$



6. For the same system of capacitors as in the previous problem, what potential difference must be applied between points X and Y so that the charge on each plate of each capacitor will have magnitude 6 microcoulombs?

- a. 1.5 V  
 b. 3 V  
**c. 6 V**  
 d. 9 V  
 e. 18 V

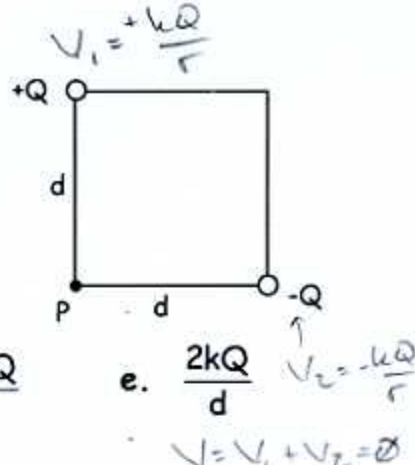


7. Two parallel conducting plates, separated by a distance  $D$ , are connected to a battery of potential difference  $V$ . Which of the following is correct if the plate separation is doubled while the battery remains connected?

- a. The electric charge on the plates is doubled.  
**b. The electric charge on the plates is halved.**  
 c. The potential difference between the plates is doubled.  
 d. The potential difference between the plates is halved.  
 e. The capacitance is unchanged.

Because  $C = \epsilon_0 A/d$ , new  $C$  will be  $C/2$ . This means half as much charge gets stored.

8. The given figure shows two charged particles, one of charge positive  $Q$  and the other of charge  $-Q$ , that are located at the opposite corners of a square with sides of length  $d$ . What is the magnitude of the electric potential at point P? (Assume potential to be zero at infinity.)

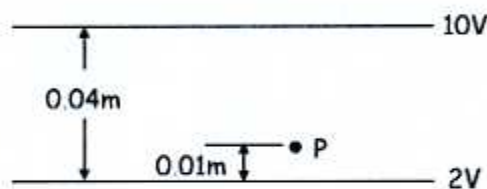


- (a) zero      b.  $\frac{kQ}{\sqrt{2}d}$       c.  $\frac{kQ}{d}$       d.  $\frac{\sqrt{2}kQ}{d}$       e.  $\frac{2kQ}{d}$

9. Two large, flat, parallel, conducting plates are 0.04m apart, as shown in the diagram. The lower plate is at a potential of 2V with respect to ground, while the upper plate is at a potential of 10V with respect to ground. Point P is located 0.01m above the lower plate. What is the magnitude of the electric field at point P?

- a. 800 V/m  
b. 600 V/m  
c. 400 V/m  
(d) 200 V/m  
e. 100 V/m

Doesn't matter which point.



$E = \frac{V}{d} = \frac{8}{0.04} = \frac{800}{4} = 200 \text{ V/m}$

10. For the same two plates and point P as used in the previous question, in which direction would an electron move, if released at point P?

- a. To the right.  
b. To the left.  
(c) Upward.  
d. Downward.  
e. Out of the plane of the page.

Electrons tend to move toward higher V.

11. Which of the following statements about conductors under electrostatic conditions is true?

- a. Positive work is required to move a positive charge over the surface of a conductor. *Nope. (Because of answer e.)*  
b. Charge that is placed on the surface of a conductor always spreads evenly over the surface. *Not for "pointy" surfaces.*  
c. The electric potential inside a conductor is always 0. *E-field is zero, but  $V_{\text{inside}} = V_{\text{surface}}$*   
d. The electric field at the surface of a conductor is tangent to the surface.  
(e) The surface of a conductor is always an equipotential surface. *Perp.*

**Problem Review:** On this portion of the test, you may use your calculator, AP formula sheet, and AP table of information. Partial credit will be given on these problems.

12. A very large vertically-oriented sheet of charge has a surface charge density of  $\sigma = -2.5 \text{ nC/m}^2$ .

- a. What is the difference in potential between two points, one of which is 1cm away from the sheet, and another of which is 8cm from the sheet and 20cm directly above the first point?



$$\oint E \cdot dA = \frac{Q_{enc}}{\epsilon_0}$$

$$E(2A_{endcap}) = \frac{\sigma A_{endcap}(\text{in middle})}{\epsilon_0}$$

$$E = \frac{\sigma}{2\epsilon_0} = \frac{2.5 \times 10^{-9}}{2\epsilon_0} = 141.2 \frac{\text{V}}{\text{m}} \text{ to left}$$

Always true for infinite sheet

$$V = -\int E \cdot ds = (141.2)(.07) = -9.88 \text{ V}$$

only in dir. of E

- b. How much work does the E-field do in moving a proton between the two points?

$$W = -q \Delta V = -(+1.6 \times 10^{-19})(-9.88) = +1.58 \times 10^{-18} \text{ J}$$

diff. in potential

Work makes sense, since proton moving toward neg charged sheet.

13. An electron starts from rest 41cm from a fixed point charge with  $Q = -2.3 \mu\text{C}$ .

- a. How fast will the electron be moving when it reaches a point 2.5m from the charge  $Q$ ?

$$\text{Initial: } U_E = qV = (-1.6 \times 10^{-19}) \left( \frac{k(-2.3 \times 10^{-6})}{.41} \right) = 8.07 \times 10^{-15} \text{ J}$$

$$\text{Final: } 8.07 \times 10^{-15} = \frac{1}{2} (9.11 \times 10^{-31}) v^2 + (-1.6 \times 10^{-19}) \left( \frac{k(-2.3 \times 10^{-6})}{2.5} \right)$$

$$v = 1.217 \times 10^8 \text{ m/s}$$

- b. How fast will the electron be moving when it reaches a point very far away from  $Q$ ?

$$U_i = K E_f \quad \leftarrow \text{No } U_f \text{ if } r = \infty$$

$$8.07 \times 10^{-15} = \frac{1}{2} (9.11 \times 10^{-31}) v^2 \rightarrow v = 1.33 \times 10^8 \text{ m/s}$$

14. A 124pF capacitor is fully charged by a 9V battery, and then disconnected from the battery. This capacitor is then connected to an uncharged 65pF capacitor. What is the charge eventually stored by this 65pF capacitor, once equilibrium is reached?

$$\text{Initial: } Q = CV = (124 \text{ pF})(9 \text{ V}) = 1116 \text{ pC}$$

$$\text{Final: } V_{65} = V_{124}$$

$$\frac{Q_{65}}{C_{65}} = \frac{Q_{124}}{C_{124}}$$

$$\frac{Q_{65}}{65} = \frac{(1116 - Q_{65})}{124}$$

$$\frac{124 Q_{65}}{65} = 1116 - Q_{65}$$

$$2.91 Q_{65} = 1116$$

$$Q_{65} = 384 \text{ pC}$$

15. Calculate the work required to assemble three charges at the corners of an equilateral triangle with 25cm-long sides, if the charges have strengths of  $+3\mu\text{C}$ ,  $-1.2\mu\text{C}$ , and  $5\mu\text{C}$ .

$$W = W_3 + W_{-1.2} + W_5 = q_3 V_3 + q_{-1.2} V_{-1.2} + q_5 V_5$$

$$= 0 + (-1.2 \times 10^{-6}) \left( \frac{k(3 \times 10^{-6})}{.25} \right) + (5 \times 10^{-6}) \left( \frac{k(3 \times 10^{-6})}{.25} + \frac{k(-1.2 \times 10^{-6})}{.25} \right)$$

$\uparrow$  1<sup>st</sup> charge assembled doesn't move through any pot. diff.  
 $\uparrow$  2<sup>nd</sup> charge only moves through pot. diff. based on 1 charge  
 $\uparrow$  3<sup>rd</sup> charge moves through pot. diff. based on 1<sup>st</sup> 2 charges.

$= 194 \text{ J}$

16. Two parallel metal plates, each with an area of  $42\text{cm}^2$ , are separated by 3mm of glass ( $k=4.8$ ), and connected across a 6V potential difference. Calculate the charge stored by the capacitor plates, and the charge induced on the surface of the glass.

$$C = k \epsilon_0 A / d = (4.8) \epsilon_0 (.0042) / .003 = 59.5 \text{ pF}$$

$$Q_{\text{free}} = CV = (59.5 \text{ pF})(6 \text{ V}) = 357 \text{ pC}$$

Gauss' Law  $\rightarrow \oint E \cdot dA = \frac{Q_{\text{free}} - Q_{\text{induced}}}{\epsilon_0}$

$$EA = \frac{Q_{\text{free}} - Q_{\text{induced}}}{\epsilon_0}$$

$$\left( \frac{6 \text{ V}}{.003 \text{ m}} \right) (.0042) = \frac{357 \times 10^{-12} - Q_{\text{induced}}}{\epsilon_0}$$

$$Q_{\text{induced}} = 283 \text{ pC}$$

17. A circular ring with a 5cm radius has a charge of  $+3\text{nC}$  spread uniformly along its length. Calculate the electric potential at a point P on the ring's central axis at a distance of 8cm above the plane of the ring.

$$V = kq/r = \frac{k(3 \times 10^{-9})}{.0943} = 285.9 \text{ V}$$

$\uparrow$  It might as well be a pt. charge, since the entire charge is 9.43 cm from P.



18. A charge of  $37\mu\text{C}$  is distributed evenly on the surface of a 15cm-radius sphere. Calculate the electric potential at a location...
- a. ... 23 cm from the sphere's center.

$$V = kq/r = \frac{k(37 \times 10^{-6})}{.23} = 1.45 \times 10^6 \text{ V}$$

outside, behaves like pt. charge

- b. ... on the sphere's surface.

$$V = \frac{k(37 \times 10^{-6})}{.15} = 2.22 \times 10^6 \text{ V}$$

- c. ... 8cm from the sphere's center.

$$2.22 \times 10^6 \text{ V}$$

Inside conductor,  $V$  stays constant throughout.

