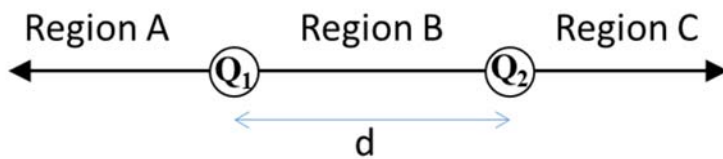


The next three questions pertain to the situation described below.

A positive and a negative charge have mass 0.4 kg and are fixed in position along the x-axis separated by a distance $d=0.2$ m as shown in below.



$Q_1 = 8.2 \times 10^{-6}$ Coulombs
 $Q_2 = -1.64 \times 10^{-5}$ Coulombs
 $d = 0.2$ m
 $m = 0.4$ kg

1) If charge Q_2 is released from rest, how fast will it be moving when it is a distance $d/4$ from charge Q_1 ?

$U_i = k \frac{Q_1 Q_2}{d_i}$
 $U_f = k \frac{Q_1 Q_2}{d_f}$
 $\Delta U = k Q_1 Q_2 \left(\frac{1}{d_f} - \frac{1}{d_i} \right)$
 $= 3 k \frac{Q_1 Q_2}{d}$

$|\Delta K| = |\Delta U|$
 $\Rightarrow \frac{1}{2} m v_f^2 = 3 k \frac{Q_1 Q_2}{d}$
 $v_f^2 = \frac{6 k Q_1 Q_2}{d m}$

a. 11 m/s
 b. 12.3 m/s
 c. 5.5 m/s
 d. 9.53 m/s
 e. 0 m/s

2) In which region(s) is there a point on the x-axis where the electric field due to the two charges is zero?

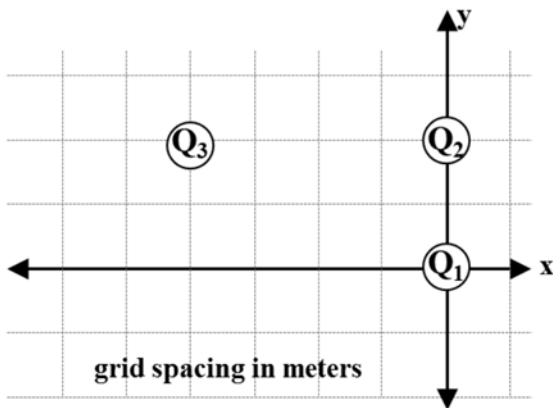
a. Region A only
 b. Region A and B.
 c. Region B only.

3) In which region(s) is there a point on the x-axis where the electric potential due to the two charges is zero?

a. Region B only.
 b. Region A only.
 c. Regions A and B.

The next three questions pertain to the situation described below.

Three charges are fixed in position as shown in below. Note, charges Q1 and Q3 are positive, charge Q2 is negative.



$$Q_1 = 2.4 \times 10^{-6} \text{ Coulombs}$$

$$Q_2 = -4.8 \times 10^{-6} \text{ Coulombs}$$

$$Q_3 = 2.4 \times 10^{-6} \text{ Coulombs}$$

$$\begin{aligned}
 U_i &= 0 \\
 U_f &= k \frac{Q_1 Q_2}{r_{12}} + k \frac{Q_1 Q_3}{r_{13}} + k \frac{Q_2 Q_3}{r_{23}} \\
 &= 9 \times 10^9 \cdot 10^{-12} \left[\frac{2.4 \cdot (-4.8)}{2} + \frac{2.4 \cdot 2.4}{\sqrt{20}} + \frac{(-4.8) \cdot 2.4}{4} \right] \\
 &= -0.0662 \text{ J}
 \end{aligned}$$

6) How much work does the **electric field** do, when the charges are brought from infinitely far away, to their location in the figure.

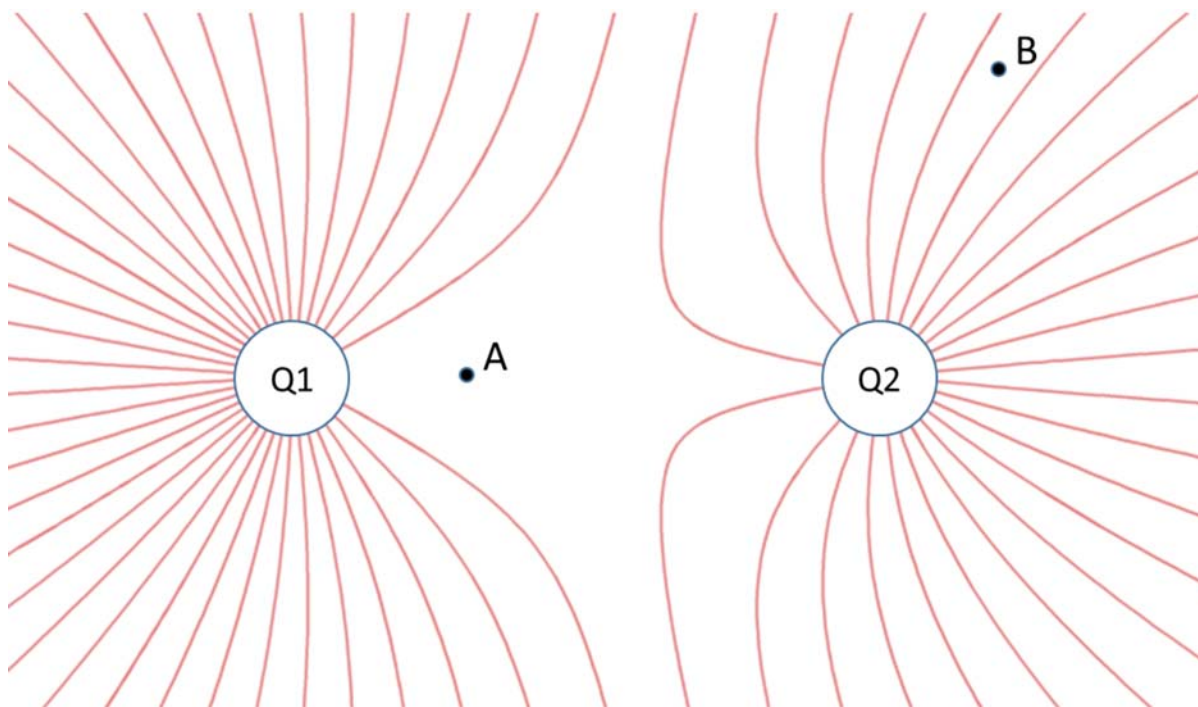
- $W_E = -0.0143 \text{ J}$
- $W_E = -0.0662 \text{ J}$
- $W_E = 0.0662 \text{ J}$
- $W_E = 0.0143 \text{ J}$
- $W_E = 0 \text{ J}$

$$W_E = -\Delta U$$

(like lowering a mass in g field)

The next two questions pertain to the situation described below.

The figure below shows the field lines due to two unknown point charges.



7) Compare the magnitude of the two charges.

- a. $|Q1| < |Q2|$
- b. $|Q1| > |Q2|$
- c. $|Q1| = |Q2|$

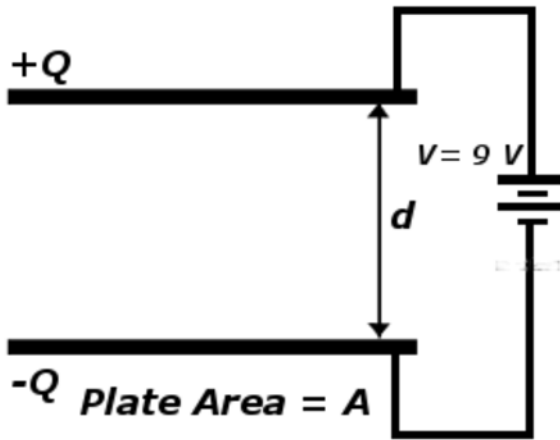
count field lines

8) Compare the magnitude of the electric field at points **A** and **B**.

- a. $|E_A| > |E_B|$
- b. $|E_A| = |E_B|$
- c. $|E_A| < |E_B|$

density of field lines

The next three questions pertain to the situation described below.



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

$$= \frac{8.85 \times 10^{-12} \cdot 542 \times 10^{-6}}{0.36 \times 10^{-3}}$$

$$= 1.33 \times 10^{-11} \text{ F}$$

A parallel plate capacitor consists of two metal plates with an area $A = 542 \text{ mm}^2$ separated by a distance $d = 0.36 \text{ mm}$. The capacitor is connected to a 9 volt battery as shown above.

16) What is the charge Q on the capacitor?

- a. $Q = 0.539 \text{ nC}$
- b. $Q = 1.08 \text{ nC}$
- c. $Q = 120 \text{ nC}$
- d. $Q = 0.12 \text{ nC}$
- e. $Q = 1.2 \times 10^{-4} \text{ nC}$

$$Q = CV$$

$$= 1.33 \times 10^{-11} \times 9$$

$$= 0.12 \times 10^{-9} \text{ C}$$

17) If the plates are pulled slightly further apart (increasing d) the magnitude of the *electric field* between the plates

- a. decreases.
- b. remains the same.
- c. increases.

fixed $V = Ed$

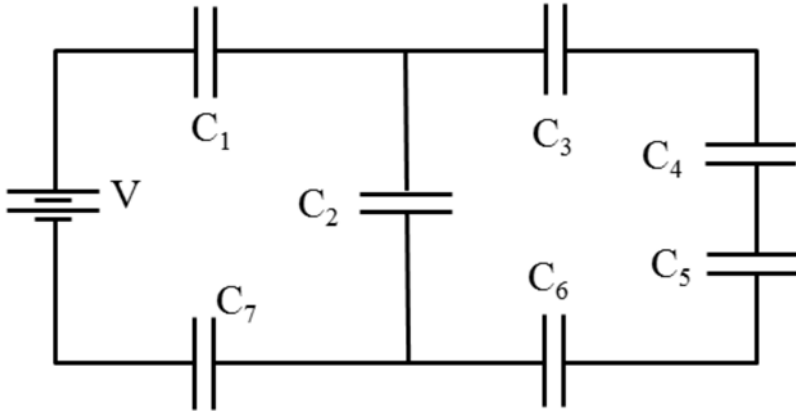
18) If a dielectric of dielectric strength κ is placed between the plates, how will the charge on the capacitor change?

- a. decrease by a factor of κ .
- b. Stay the same.
- c. Increase by a factor of κ .

$$C = \kappa C_0$$

$$Q = CV$$

The next four questions pertain to the situation described below.



Seven identical capacitors with capacitance $C = 8.5 \text{ nF}$ are connected to a 12 Volt battery as shown in the figure above.

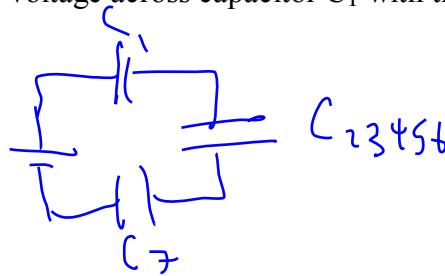
19) Capacitors C_3 and C_6 are connected

A single wire connects them

- a. in parallel.
- b. in series.
- c. neither in series nor in parallel.

20) Compare the magnitude of the voltage across capacitor C_1 with the magnitude of the voltage across capacitor C_7

- a. $V_1 = V_7$
- b. $V_1 > V_7$
- c. $V_1 < V_7$



$Q_1 = Q_{23456} = Q_7$
 $V = \frac{Q}{C}$

21) What is the equivalent capacitance of the network of seven capacitors?

- a. $C_{eq} = 9.92 \text{ nF}$
- b. $C_{eq} = 9.07 \text{ nF}$
- c. $C_{eq} = 23.8 \text{ nF}$
- d. $C_{eq} = 3.04 \text{ nF}$
- e. $C_{eq} = 1.21 \text{ nF}$

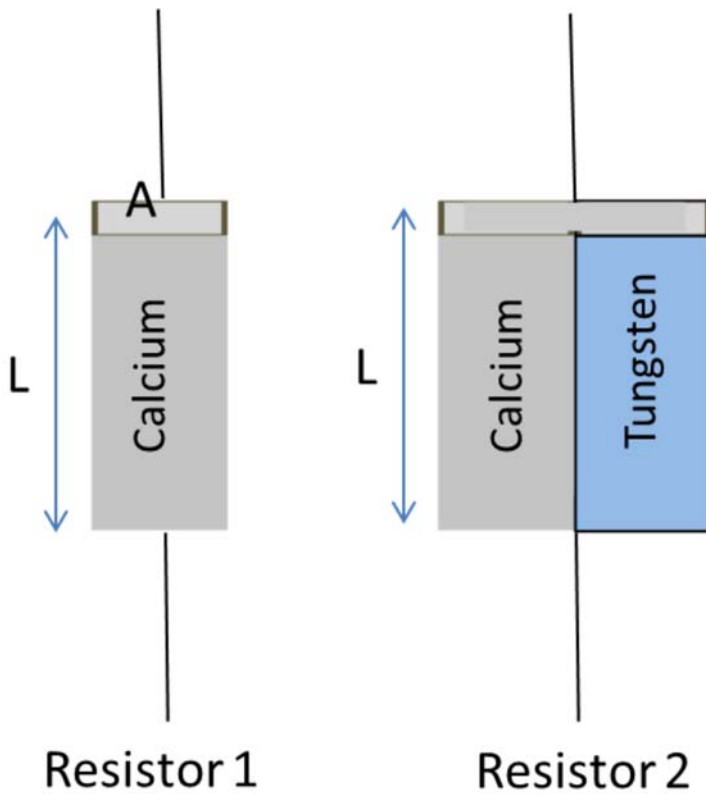
$C_{3456} = \frac{C}{4} \Rightarrow C_{23456} = \frac{5}{4}C$
 $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_7} + \frac{1}{C_{23456}} = \frac{2.8}{C}$

22) What is the voltage across capacitor C_2 ?

- a. $V_2 = 3.4 \text{ Volts}$
- b. $V_2 = 4 \text{ Volts}$
- c. $V_2 = 0.85 \text{ Volts}$

$Q = C_{eq}V = 3.64 \times 10^{-8} \text{ C}$
 $V_2 = \frac{Q_2}{C_2}$
 $V_{3456} = \frac{Q_{3456}}{C_{3456}}$
 $Q_1 = Q_2 + Q_{3456} = Q_2 \left[1 + \frac{1}{4} \right] = \frac{5}{4}Q_2$
 $Q_2 = \frac{4}{5}Q_1$
 $V_2 = \frac{Q_2}{C}$
 $V_2 = V_{3456} \Rightarrow Q_{3456} = \frac{C_{3456}}{C_2} Q_2$

The next two questions pertain to the situation described below.



$$R = \frac{\rho L}{A}$$

A student decides to build some resistors using rectangular blocks of calcium ($\rho = 3.36 \times 10^{-8} \Omega \text{ m}$) and tungsten ($\rho = 5.6 \times 10^{-8} \Omega \text{ m}$). The dimensions of the blocks are identical with a length $L = 0.12 \text{ m}$, and cross section $A = 2.25 \times 10^{-4} \text{ m}^2$. Resistor 1 is created from a single block of calcium. Resistor 2 is created by attaching a block of calcium to a block of tungsten as shown in the figure above.

23) Compare the resistance of the two resistors.

- a. $R_1 = R_2$
- b. $R_1 > R_2$
- c. $R_1 < R_2$

Basically 2 resistors in parallel

24) What is the resistance of resistor 2?

- a. $R_2 = 1.12 \times 10^{-5} \Omega$
- b. $R_2 = 4.78 \times 10^{-5} \Omega$
- c. $R_2 = 2.39 \times 10^{-5} \Omega$

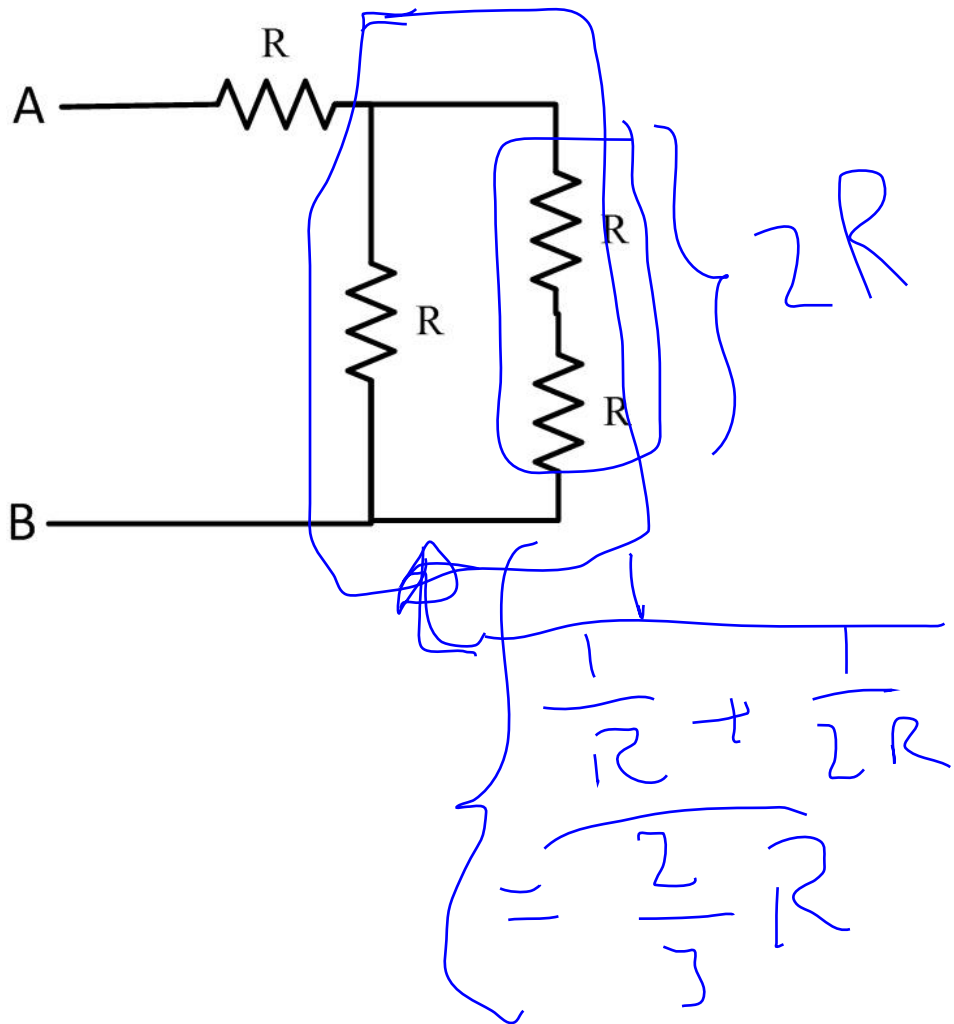
$$\frac{1}{R_2} = \frac{1}{R_{Ca}} + \frac{1}{R_{W}}$$

$$\Rightarrow \frac{1}{R_2} = \frac{1}{L} \left(\frac{1}{\rho_{Ca}} + \frac{1}{\rho_{W}} \right)$$

Physics 102 Exam 1 --
Spring 2014

1. d
2. a
3. c
4. c
5. e
6. c
7. b
8. c
9. b
10. c
11. b
12. b
13. a
14. d
15. a
16. cd
17. a
18. c
19. b
20. a
21. d
22. a
23. b
24. a

3. What is the resistance between points A and B of the resistor network shown in the diagram below? Each resistor in the network has resistance R .



- a. $5R/2$
- b. $3R/5$
- c. $5R/3$
- d. $4R$
- e. $R/4$

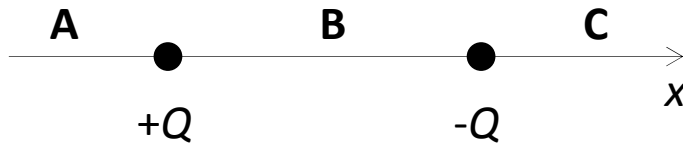
4. Animal fat has a resistivity $\rho = 7 \Omega \cdot \text{m}$. What is the resistance of a cylinder of animal fat that has a radius of 0.5 m and a length of 1 m ?

- a. 0.79Ω
- b. 0.0079Ω
- c. 1.6Ω
- d. 12500Ω
- e. 8.9Ω

$$R = \frac{\rho L}{A} = \frac{\rho L}{\pi r^2}$$

9. Two charges, $+Q$ and $-Q$, are placed on the x -axis as shown. In which of the three regions, **A**, **B**, and **C**, on the x -axis can the electric field be zero?

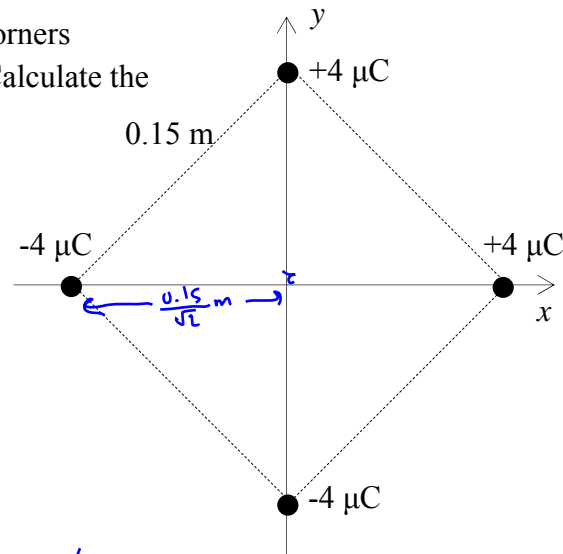
- a. Region **A**
- b. Region **B**
- c. Region **C**
- d. Regions **A** and **C**
- e. No regions.



Approaches 0 at $\frac{1}{3}$

10. Four charges, all $\pm 4 \mu\text{C}$, are placed at the corners of a square with 0.15 m long sides, as shown. Calculate the x -component, E_x , of the electric field at the center of the square.

- a. $E_x = -6.4 \times 10^6 \text{ N/C}$
- b. $E_x = -3.2 \times 10^6 \text{ N/C}$
- c. $E_x = 0 \text{ N/C}$
- d. $E_x = +3.2 \times 10^6 \text{ N/C}$
- e. $E_x = +6.4 \times 10^6 \text{ N/C}$



only left and right charges cause E_x
 both charges cause E to left

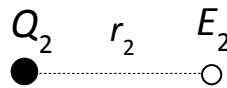
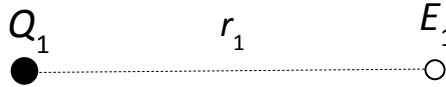
$$|E_{\text{tot}}| = 2 \cdot \frac{k|Q|}{r^2} = 2 \cdot \frac{9 \times 10^9 \cdot 4 \times 10^{-6}}{\left(\frac{0.15}{\sqrt{2}}\right)^2}$$

$$= 6.4 \times 10^6 \text{ N/C}$$

to the left

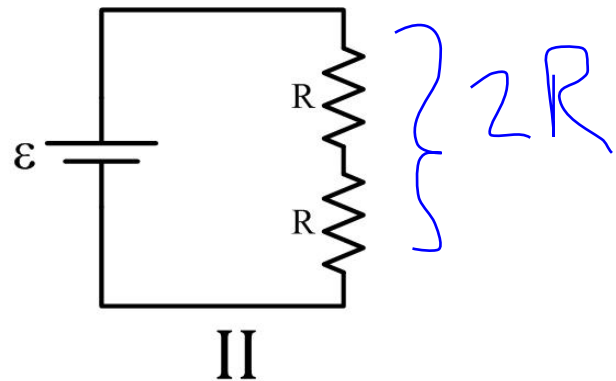
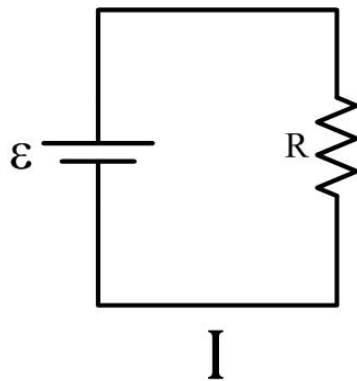
11. Compare the magnitudes of the electric fields, E_1 and E_2 , produced by two charges, $Q_1 = 3.2 \mu\text{C}$ and $Q_2 = 0.75 \mu\text{C}$. We measure E_1 a distance $r_1 = 0.2 \text{ m}$ from Q_1 , and E_2 a distance $r_2 = 0.1 \text{ m}$ from Q_2 . Which is larger, E_1 or E_2 ?

- a. E_1 is larger.
- b. E_1 and E_2 are equal.
- c. E_2 is larger.



$$E = \frac{kQ}{r^2}$$

12. Consider the two circuits, labeled I and II, in the circuit below. All resistors have the same resistance R , and the batteries both have the same emf ϵ .



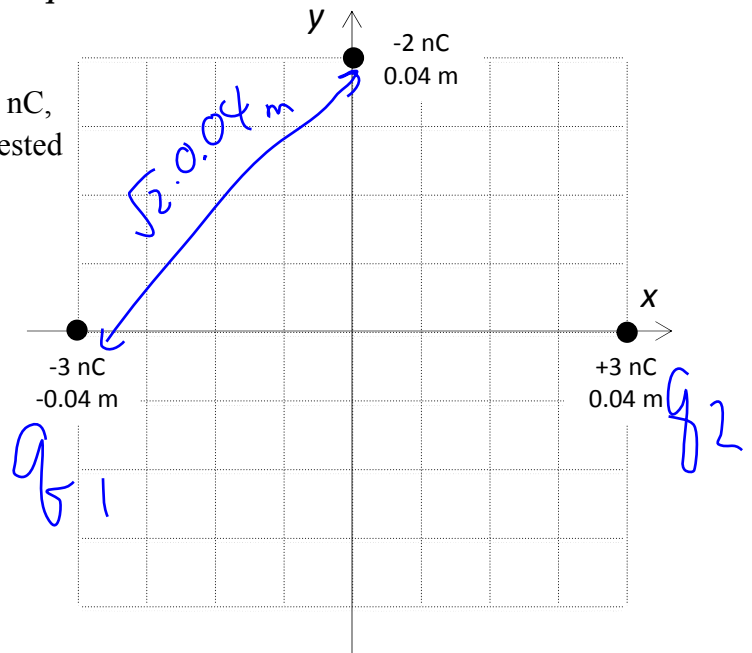
Which of the following statements is true regarding the power P_I supplied by the battery in circuit I compared with the power P_{II} supplied by the battery in circuit II?

- a. $P_I = 2 P_{II}$
- b. $P_I = 0.5 P_{II}$
- c. $P_I = 0.25 P_{II}$
- d. $P_I = 4 P_{II}$
- e. $P_I = P_{II}$

$$P = V^2 / R$$

The following situation pertains to the next three questions.

A positive charge, $+3\text{nC}$ is placed at $+0.04\text{ m}$ on the x -axis. A negative charge, -3 nC , is placed at -0.04 m on the x -axis. We are interested in the electric force on a -2 nC charge placed at $+0.04\text{ m}$ on the y -axis.



15. What is the electric potential at the position of the -2 nC particle, due to the two charges on the x -axis? The electric potential is defined to be zero at infinity.

- a. -955 V
- b. -477 V
- c. 0 V
- d. 477 V
- e. 955 V

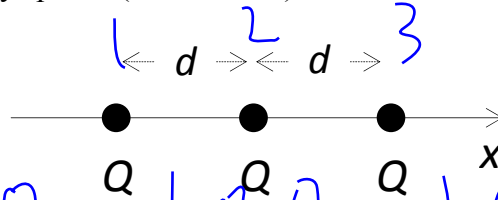
$$V = k \frac{q_1}{d_1} + k \frac{q_2}{d_2}$$

$$q_1 = -q_2, d_1 = d_2 \Rightarrow V = 0$$

The following two problems are related.

16. How much work must you do to assemble the charge configuration shown? All three charges have $Q = -1.5 \mu\text{C}$ and are equally spaced ($d = 0.035 \text{ m}$) on the x -axis.

- a. 1.16 J
- b. 1.45 J**
- c. 1.74 J
- d. $9.64 \times 10^5 \text{ J}$
- e. $1.16 \times 10^6 \text{ J}$



$$U = k \frac{Q_1 Q_2}{d_{12}} + k \frac{Q_1 Q_3}{d_{13}} + k \frac{Q_2 Q_3}{d_{23}}$$

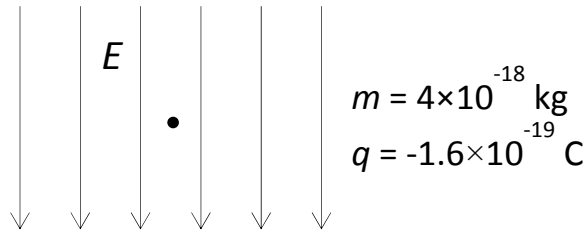
$$= k Q^2 \left[\frac{1}{d} + \frac{1}{2d} + \frac{1}{d} \right]$$

17. Suppose the charges in the previous problem all had $Q = +1.5 \mu\text{C}$. How would your answer change?

- a. The work would become less positive (or more negative).
- b. The work would not change.**
- c. The work would become more positive (or less negative).

18. A small particle of mass $m = 4 \times 10^{-18} \text{ kg}$ has a charge of $q = -1.6 \times 10^{-19} \text{ C}$. It is placed in a vertical electric field, E , as shown. What must the magnitude of E be to suspend the particle against the force of gravity?

- a. 0.04 N/C
- b. 25 N/C**
- c. 245 N/C**



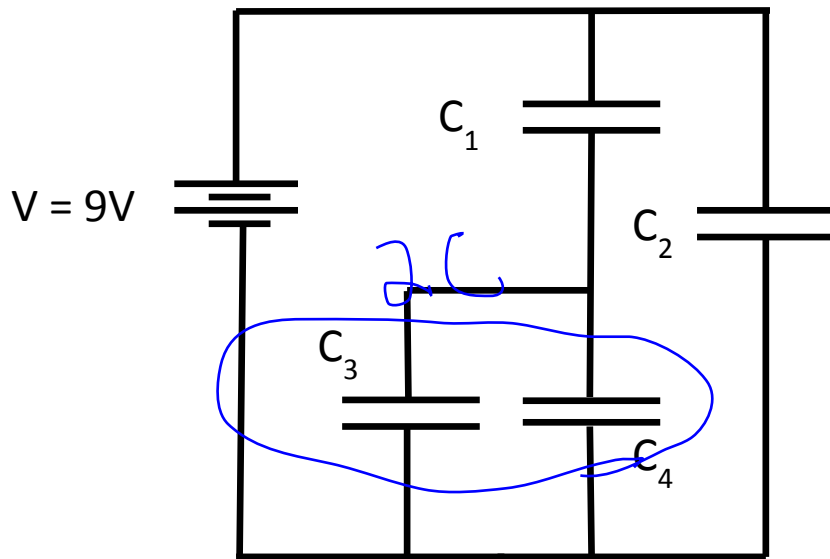
$$mg = qE$$

$$E = \frac{mg}{q} = \frac{4 \times 10^{-18} \cdot 9.8}{1.6 \times 10^{-19}} \left[\frac{\text{kg m/s}^2}{\text{C}} \right]$$

$$= 245 \text{ N/C}$$

The next two problems refer to the capacitor network shown below.

The circuit consists of 4 capacitors C_1 , C_2 , C_3 and C_4 and a battery with a voltage of 9 V. All capacitors have identical values $C = C_1 = C_2 = C_3 = C_4$.



$$C_{134} = \frac{2}{3}C$$

$$C_{234} = \frac{5C}{3}$$

19. What is the equivalent capacitance C_{eq} of the circuit in terms of $C = C_1 = C_2 = C_3 = C_4$?

- a. $C/3$
- b. $2C/3$
- c. $5C/3$
- d. $7C/3$
- e. $3C$

20. If $C = 15 \text{ mF}$, what is the electric charge Q_2 stored in capacitor C_2 ?

- a. 0.045 C
- b. 0.135 C
- c. 0.225 C

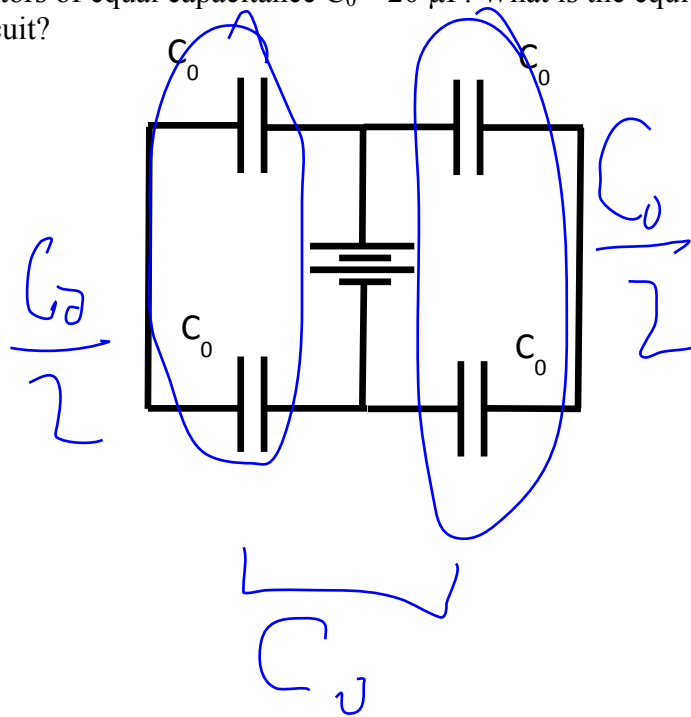
C_2 connected to battery

$$\Rightarrow V_2 = V = 9V$$

$$Q = C_2 V = 15 \times 10^{-3} (9) C$$

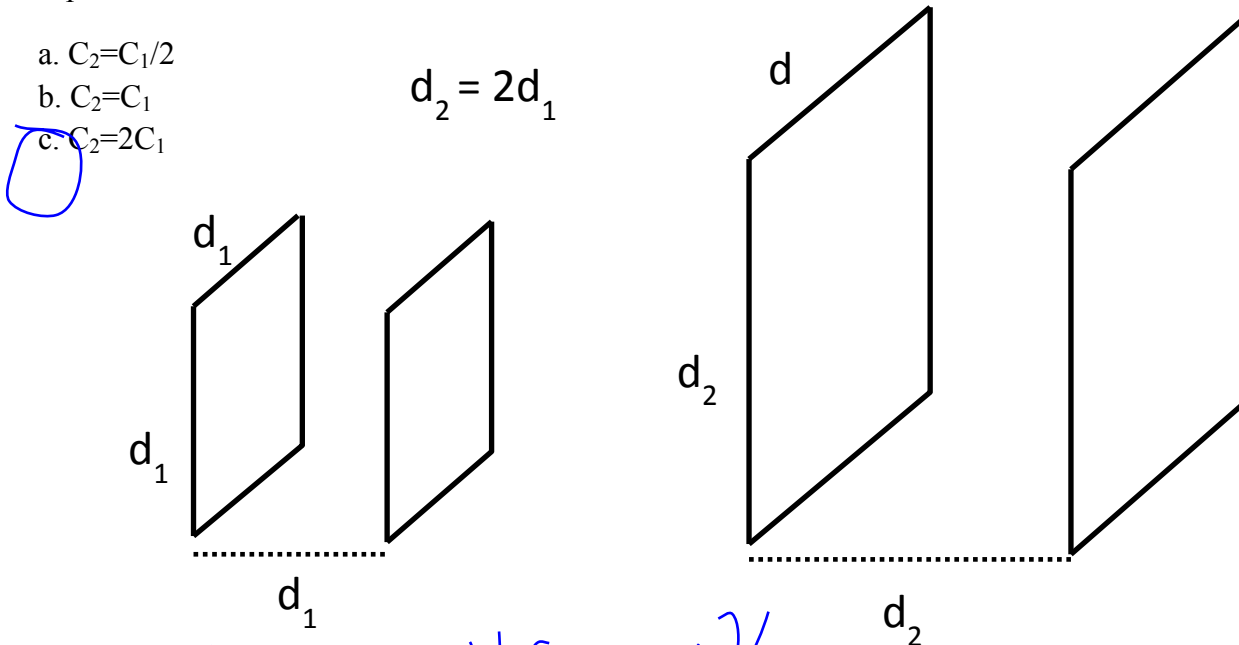
21. A circuit has 4 capacitors of equal capacitance $C_0 = 20 \mu\text{F}$. What is the equivalent capacitance C_{eq} of the circuit?

- a. $C_{\text{eq}} = 10 \mu\text{F}$
- b. $C_{\text{eq}} = 20 \mu\text{F}$
- c. $C_{\text{eq}} = 30 \mu\text{F}$
- d. $C_{\text{eq}} = 40 \mu\text{F}$
- e. $C_{\text{eq}} = 50 \mu\text{F}$



22. Two capacitors are made from two square sheets of copper plates. For each of the capacitors the length of the sides of the sheets is identical to the distance between the two plates. The distances between plates for the first capacitor with capacitance C_1 is d_1 , and $d_2 = 2d_1$. What is the capacitance C_2 in terms of C_1 ?

- a. $C_2 = C_1/2$
- b. $C_2 = C_1$
- c. $C_2 = 2C_1$



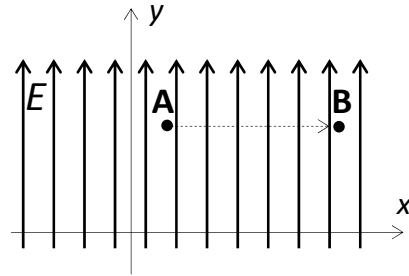
$$C = \frac{\epsilon_0 A}{d} = K \epsilon_0 \frac{d^2}{d} = K \epsilon_0 d$$

23. A charged particle ($q = 0.5 \mu\text{C}$) moves in a uniform electric field ($E = 1.2 \times 10^7 \text{ N/C}$, in the $+x$ direction) from **A** to **B** as shown. The starting point, **A**, is at $(x=0.15 \text{ m}, y=0.14 \text{ m})$, and the ending point, **B**, is at $(x=0.215 \text{ m}, y=0.14 \text{ m})$. How much work does the electric field do on the particle as it moves from **A** to **B**?

- a. -1.2 J
- b. 0 J
- c. +1.2 J

$$W = F \cdot d \cos \theta$$

$$= 0$$



24. A collection of large capacitors connected in parallel is used in operating an accelerator in a radiation oncology practice. The total capacitance is $C = 1\text{F}$. Assuming the capacitors are operated with a voltage of $V=110 \text{ V}$, how much energy can be stored?

- a. 55 J
- b. 305 J
- c. 610 J
- d. 6050 J
- e. 12100 J

$$U = \frac{1}{2} CV^2$$

25. A naval rail gun has accelerated a projectile to 3km/s . The projectile has a kinetic energy of 490kJ . The energy for rail gun shots is stored in large capacitors. If the capacitance used is $C_R=2\text{F}$, how much charge was stored in the capacitor just before the shot was fired?

- a. 70 C
- b. 490 C
- c. 700 C
- d. 1400 C
- e. 2800 C

$$U = \frac{1}{2} \frac{Q^2}{C} ; U = 490 \text{ kJ}$$

$$\Rightarrow Q^2 = 2 \cdot 2 (490 \times 10^3) \text{ J}$$

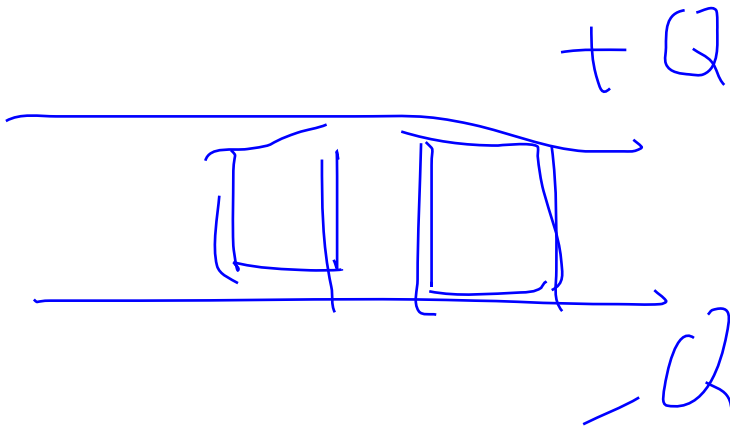
$$Q = 1400 \text{ C}$$

26. Two large parallel aluminum plates are isolated and separated by an adjustable distance. A container of water (with dielectric constant $\epsilon=80$) has been placed between the plates. Which change to the setup would increase the capacitance of the plates?

a. Increasing the distance between the two plates. ~~X~~

b. Removing the container of water. ~~X~~

c. Adding a second container of water between the plates while keeping the distance between them fixed.



**Check to make sure you bubbled in all your answers.
Did you bubble in your name, exam version and network-ID?**

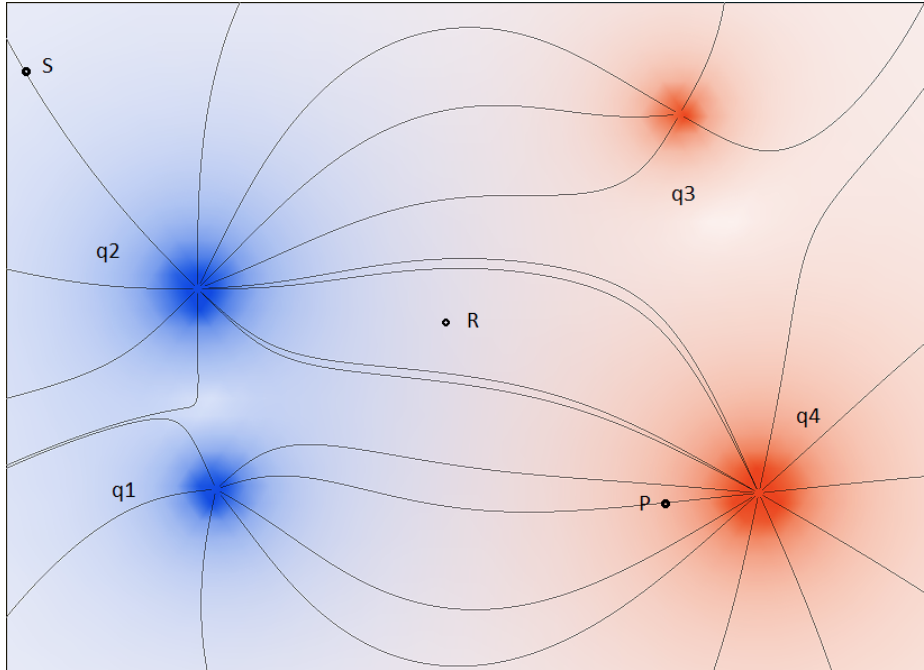
KEY

Exam 1 – Fall 2012

1. a
2. b
3. c
4. e
5. a
6. c
7. b
8. c
9. e
10. a
11. a
12. a
13. a
14. d
15. c
16. b
17. b
18. c
19. c
20. b
21. b
22. c
23. b
24. d
25. d
26. c
27. c

The next three questions pertain to the situation described below.

Consider the collection of 4 charges below:



10) Using the field lines determine the correct ordering for the magnitudes of the charges

- a. $|q_3| < |q_1| < |q_2| < |q_4|$
 - b. $|q_2| < |q_1| < |q_4| < |q_3|$
 - c. $|q_3| < |q_2| < |q_1| < |q_4|$
 - d. $|q_1| < |q_2| < |q_3| < |q_4|$
 - e. $|q_1| < |q_3| < |q_2| < |q_4|$
- Count field lines

11) Based on the nature of the field lines which of the following is true:

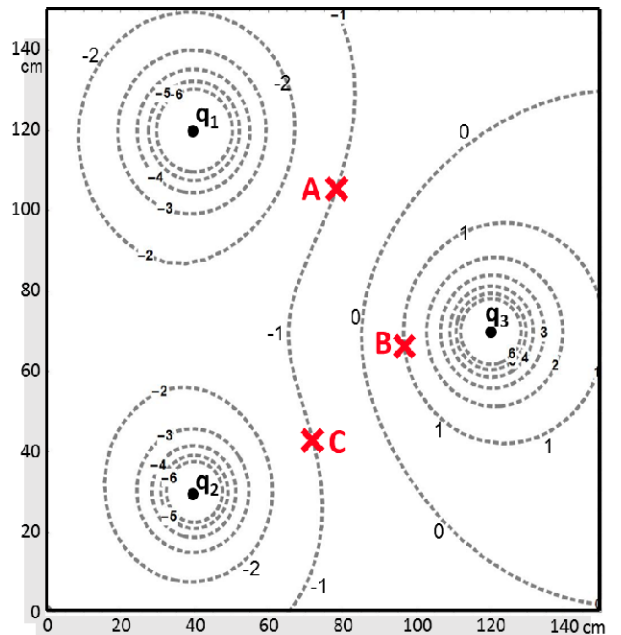
- a. The signs of q_1 and q_2 are opposite of q_3 and q_4 .
 - b. All of the charges have the same sign.
 - c. The charges q_1 and q_4 have the same sign.
- q_1 connects q_3, q_4
 q_2 " " " "

12) When placed at which point will a test charge experience the largest force?

- a. P
 - b. R
 - c. S
- density of field lines

The next two questions pertain to the situation described below.

Given is a map of equal-potential lines (see figure). The potential is created by three charges in a plane (q_1 , q_2 , q_3). **Potential values are given in Volts**. Note the signs (+/-). Based on the map:



16) What is the sign (+/-) of the charge q_2 ?

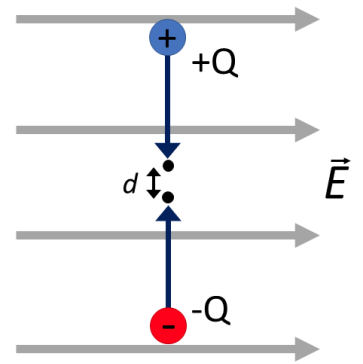
- a. +
- b. -
- c. 0

17) How much total work W by you is required to move a charge of 1 C from point A to point B , and then from point B to point C ?

- a. $W = 0\text{ J}$
- b. $W = 4\text{ J}$
- c. $W = -2\text{ J}$
- d. $W = 2\text{ J}$
- e. $W = -4\text{ J}$

A, C at same potential

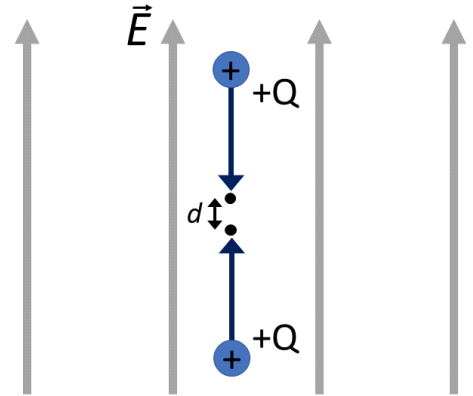
18) You move two charges closer towards each other by equal distances, until they are separated by a small distance d . They have equal masses and charges of equal magnitude and opposite sign, Q and $-Q$. The charges are exposed to a uniform electric field E , as shown in the diagram. Keeping in mind interactions between the two objects, which statement best describes the work done by you on the system of charges?



$\Delta U < 0$

- a. I am doing negative work on the system of charges.
- b. I am doing positive work on the system of charges.
- c. I am doing no work on the system of charges.

19) Choose the statement that best describes the work done by you on the system shown. The objects have equal charge Q , and the direction of electric field is vertical.



$\Delta U > 0$

- a. I am doing positive work on the system of charges.
- b. I am doing negative work on the system of charges.
- c. I am doing no work on the system of charges.

20) Consider the case of two identical charges, with equal mass $M = 0.7 \text{ kg}$ and equal charge $Q = +6 \text{ C}$, in the absence of an external electric field. The charges start at an infinitely far distance apart, and move in opposite directions directly towards one another, with velocities of $+5 \text{ km/s}$ and -5 km/s , respectively. What is the closest distance d that the charges will get to one another?

- a. $d = 8700 \text{ m}$
- b. $d = 58 \text{ m}$
- c. $d = 2 \times 10^3 \text{ m}$
- d. $d = 150 \text{ km}$
- e. $d = 19 \text{ km}$

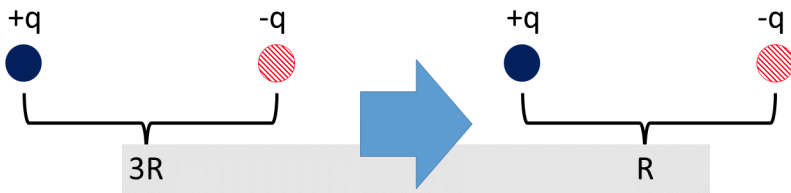
Handwritten solution for Q20:

$$K_i = 2 \cdot \frac{1}{2} m v^2 \quad U_i = 0$$

$$K_f = 0 \quad U_f = \frac{k q_1 q_2}{d}$$

$$\Rightarrow d = \frac{k q^2}{m v^2} = 18.5 \text{ km}$$

21) What is the change in potential energy of a particle of charge $+q$ that is brought from a distance of $3R$ to a distance of R from a particle of charge $-q$?



- a. $U = -2kq^2/3R$
- b. $U = -kq^2/4R^2$
- c. $U = -2kq^2/R$
- d. $U = kq^2/3R$
- e. $U = kq^2/3R^2$

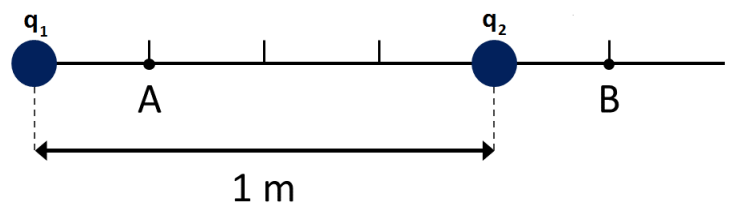
Handwritten solution for Q21:

$$U_f - U_i = \frac{k q (-q)}{R} - \frac{k (q) (-q)}{3R}$$

$$= -\frac{2}{3} \frac{k q^2}{R}$$

22) Two $2.9 \mu\text{C}$ charges are held fixed at the positions shown in the figure. Note that both charges are positive.

Calculate the change in potential energy $U(B) - U(A)$ of a $1.0 \mu\text{C}$ charge that is moved from A to B . Note that the ruler lines shown in the figure are equally spaced.



- a. $U = -0.014 \text{ J}$
- b. $U = -0.042 \text{ J}$
- c. $U = 0 \text{ J}$
- d. $U = 0.042 \text{ J}$
- e. $U = 0.014 \text{ J}$

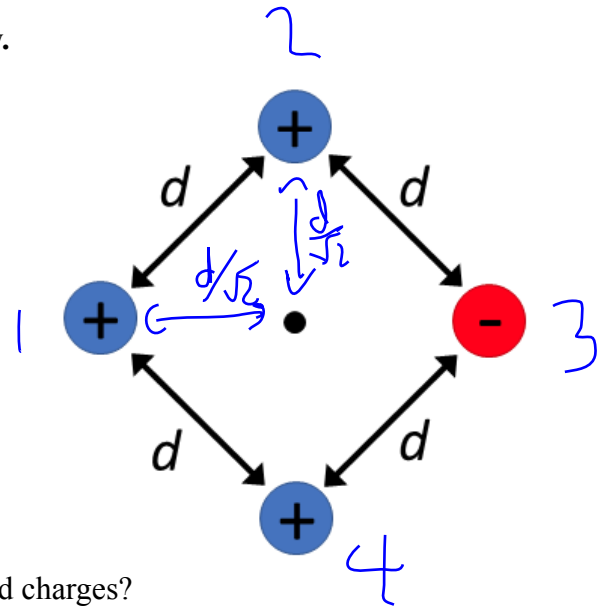
Handwritten solution for Q22:

$$U_A = \frac{k q q_1}{\frac{1}{4}(1 \text{ m})} + \frac{k q q_2}{\frac{3}{4}(1 \text{ m})} = k q q_1 \left(\frac{4}{1 \text{ m}} \right)$$

$$U_B = \frac{k q q_1}{\left(\frac{1}{4} \right) 5 \text{ m}} + \frac{k q q_2}{(1 \text{ m}) \left(\frac{1}{4} \right)} = k q q_1 \left(\frac{4}{5 \text{ m}} \right)$$

The next three questions pertain to the situation described below.

Four point charges are equally spaced by a distance $d = 4.69 \text{ mm}$ at the corners of a square, as shown in the figure. Three of the charges are positive, with $q = 2.9 \mu\text{C}$, while one is negative with charge $q = -2.9 \mu\text{C}$.

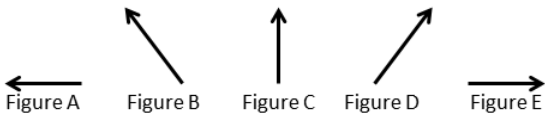


23) What is the electric potential at the center point between the fixed charges?

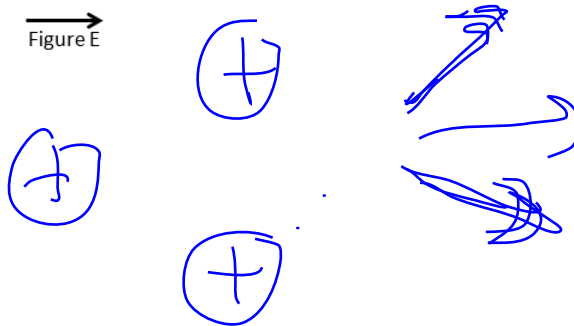
- a. $V = -1.6 \times 10^7 \text{ V}$
- b. $V = 1.6 \times 10^7 \text{ V}$
- c. $V = 2.2 \times 10^7 \text{ V}$
- d. $V = -1.1 \times 10^7 \text{ V}$
- e. $V = 1.1 \times 10^7 \text{ V}$

$$\begin{aligned}
 V &= V_1 + V_2 + V_3 + V_4 \\
 &= \frac{kq}{d/\sqrt{2}} + \frac{kq}{d/\sqrt{2}} - \frac{kq}{d/\sqrt{2}} + \frac{kq}{d/\sqrt{2}} \\
 &= 2\sqrt{2} \frac{kq}{d}
 \end{aligned}$$

24) Considering only the three positive charges, which vector arrow shown below best represents the direction of the electric field at the position of the negative charge?



- a. Figure A
- b. Figure B
- c. Figure C
- d. Figure D
- e. Figure E



25) Considering only the three positive charges, what is the magnitude of the electric field at the position of the negative charge?

- a. $E = 1.19 \times 10^9 \text{ N/C}$
- b. $E = 2.27 \times 10^9 \text{ N/C}$
- c. $E = 0 \text{ N/C}$
- d. $E = 1.78 \times 10^9 \text{ N/C}$
- e. $E = 1.08 \times 10^9 \text{ N/C}$

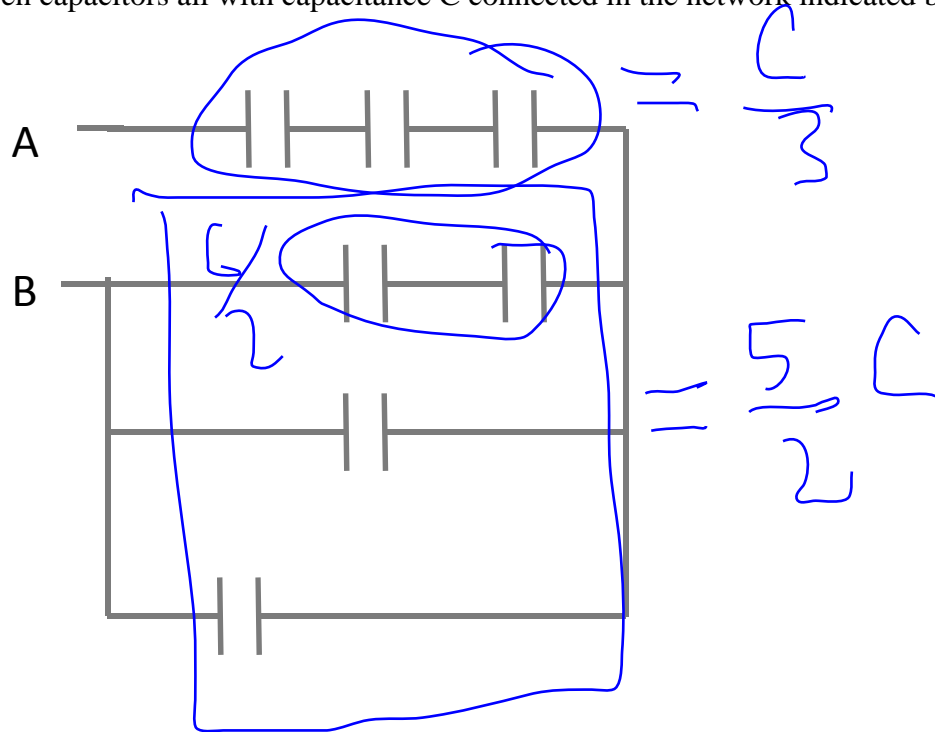
$$\begin{aligned}
 E_{1x} &= \frac{kq}{(2d/\sqrt{2})^2} ; E_{2x} = \frac{kq}{d^2} \\
 E_{\text{tot}} &= \frac{kq}{d^2} \left[\frac{1}{2} + 2 \left(\frac{1}{\sqrt{2}} \right) \right] \\
 &= \frac{kq}{d^2} \left(\frac{1}{2} + \sqrt{2} \right)
 \end{aligned}$$

KEY

Exam 1 – Fall 2014

1. a
2. a
3. d
4. b
5. c
6. a
7. c
8. abc
9. e
10. a
11. a
12. a
13. e
14. e
15. b
16. b
17. a
18. a
19. a
20. e
21. a
22. a
23. b
24. d
25. b

1. There are seven capacitors all with capacitance C connected in the network indicated below.



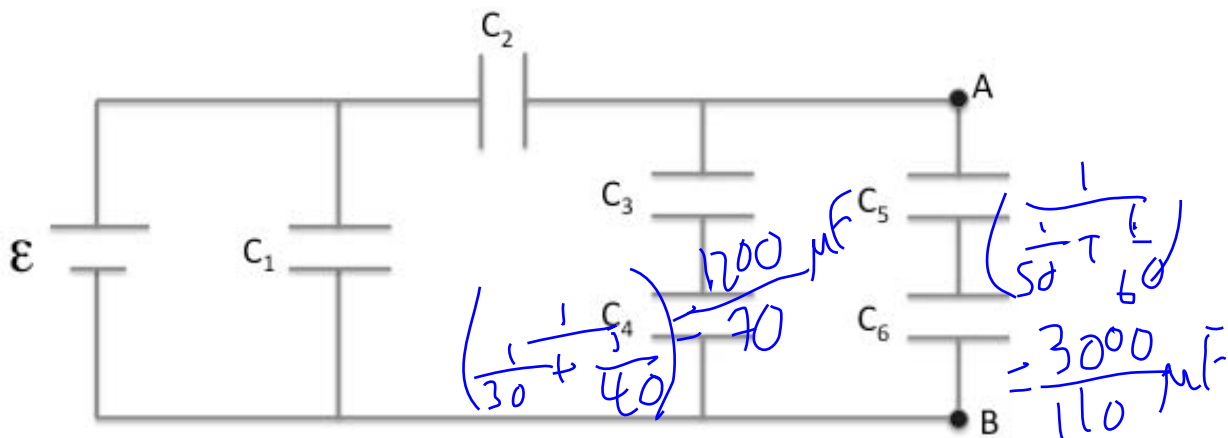
What is the equivalent capacitance of this network between points A and B?

- a. $5/6 C$
- b. $2/3 C$
- c. $5/17 C$
- d. $20/5 C$
- e. $42/7 C$

$$\begin{aligned}
 C_{eq} &= \frac{1}{\left(\frac{C}{3}\right) + \left(\frac{5}{2}C\right)} \\
 &= \frac{1}{C \left[3 + \frac{2}{5} \right]} = \frac{17}{5} C
 \end{aligned}$$

The following situation pertains to the next three questions:

A network of fully charged capacitors and a battery is drawn below. The components have the following values: $C_1 = 10 \mu\text{F}$, $C_2 = 20 \mu\text{F}$, $C_3 = 30 \mu\text{F}$, $C_4 = 40 \mu\text{F}$, $C_5 = 50 \mu\text{F}$, $C_6 = 60 \mu\text{F}$, and $\mathcal{E} = 12 \text{ Volts}$. The points A and B are labeled on the diagram.



2. What is the equivalent capacitance of this entire network?

- a. $C_{eq} = 23.8 \mu\text{F}$
- b. $C_{eq} = 123.5 \mu\text{F}$
- c. $C_{eq} = 52.8 \mu\text{F}$
- d. $C_{eq} = 100.1 \mu\text{F}$
- e. $C_{eq} = 65.9 \mu\text{F}$

Handwritten calculations:
 $C_{3456} = 44.4 \mu\text{F}$
 $\frac{1}{C_{23456}} = \frac{1}{20 \mu\text{F}} + \frac{1}{44.4 \mu\text{F}}$
 $C_{23456} = 13.8 \mu\text{F}$
 $C_{eq} = C_1 + C_{23456}$

3. What is the electric charge stored on capacitor C_1 ?

- a. $Q_2 = 95.1 \mu\text{C}$
- b. $Q_2 = 120.0 \mu\text{C}$
- c. $Q_2 = 131.0 \mu\text{C}$
- d. $Q_2 = 85.3 \mu\text{C}$
- e. $Q_2 = 201.3 \mu\text{C}$

Handwritten calculations:
 $V_1 = \mathcal{E}$
 $Q = C_1 V_1 = C_1 \mathcal{E}$

4. Suppose the branch from point A to point B, including capacitors C_5 and C_6 , were removed from the circuit. The charge stored on C_1 would

- a. increase.
- b. decrease.
- c. stay the same.

The next three questions pertain to the following situation:

A capacitor is in a circuit with a battery as shown. This capacitor has square plates with sides $s = 2.2$ cm and has no dielectric between the plates. Each plate has a charge of magnitude $Q = 10$ pC.

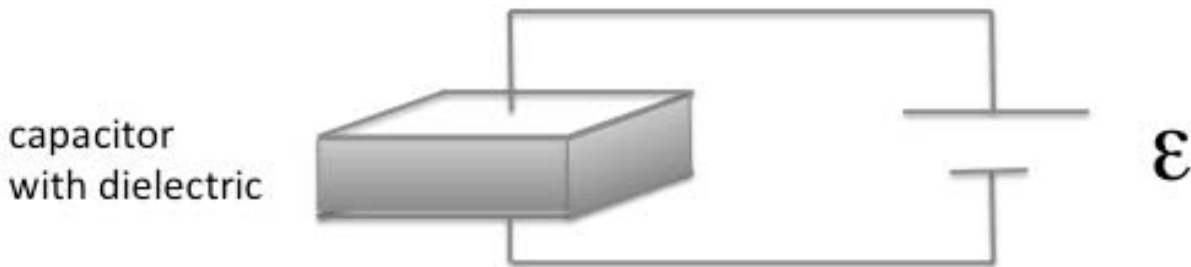


5. What is the electric field, E , between the plates?

- a. $E = 2.33 \times 10^3$ N/C
 b. $E = 1.54 \times 10^3$ N/C
 c. $E = 3.14 \times 10^4$ N/C
 d. $E = 5.98 \times 10^3$ N/C
 e. $E = 6.79 \times 10^4$ N/C

$$E = \frac{Q}{\epsilon_0 A} = \frac{10 \times 10^{-12} \text{ C}}{\epsilon_0 (0.022 \text{ m})^2}$$

6. The capacitor has a stored energy, U_1 , without any dielectric between the plates. Now a slab of dielectric material with dielectric constant $K = 2.0$ is placed between the plates, with the same width as the plate separation.



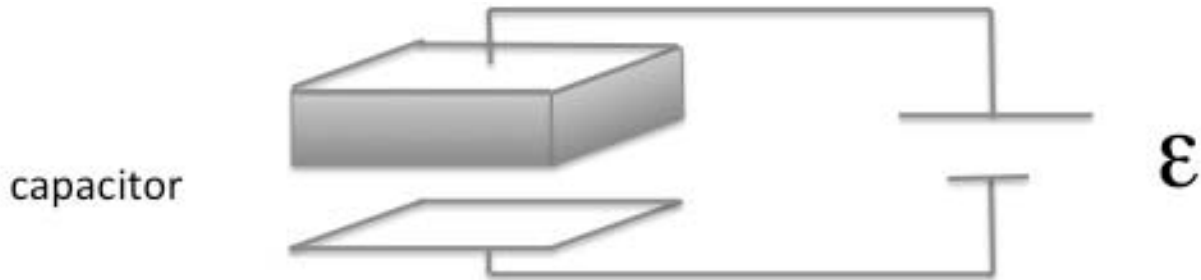
The new stored energy of the capacitor U_2 is

- a. the same as U_1 .
 b. less than U_1 .
 c. larger than U_1 .

$$U = \frac{1}{2} CV^2 ; C = KC_0$$

The next question continues from the previous page.

7. A conducting slab replaces the dielectric, and the distance between the plates is doubled. The stored energy is now U_3 .

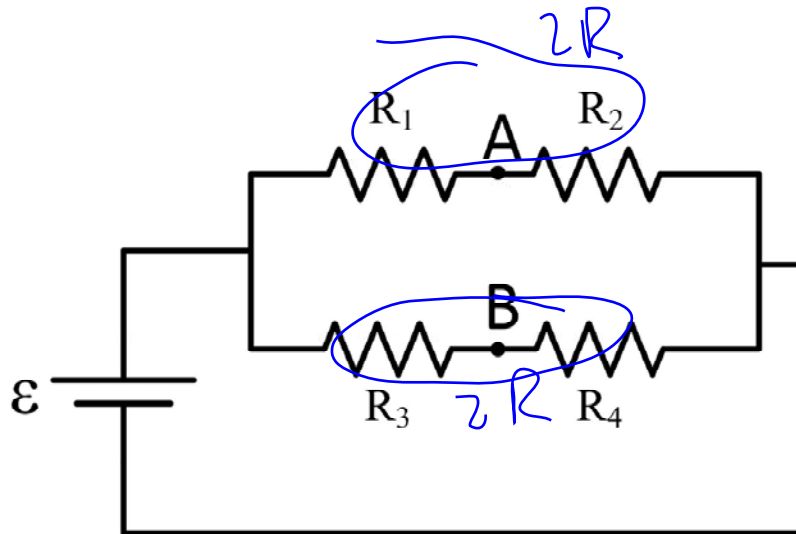


Compare this stored energy U_3 with the original stored energy U_1 .

- a. $U_3 = 3/2 U_1$
- b. $U_3 = 4 U_1$
- c. $U_3 = U_1$
- d. $U_3 = 1/4 U_1$
- e. $U_3 = 2/3 U_1$

distance between
bottom of conducting
slab is what
matters now

The next four questions refer to the following circuit:



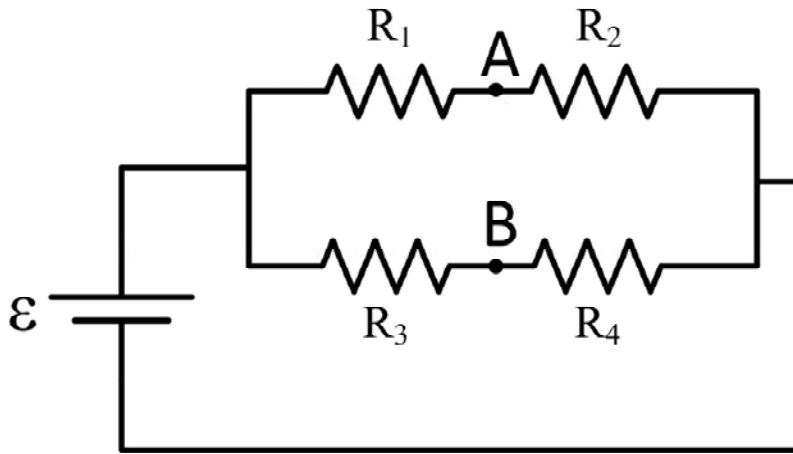
8. If all four resistors have resistance R , what is the total equivalent resistance for this circuit?

- a. $4R$
- b. $2R$
- c. R
- d. $R/4$
- e. $R/2$

9. What is the current supplied by the battery if each resistor has resistance R ?

- a. \mathcal{E}/R
- b. $2R/\mathcal{E}$
- c. $\mathcal{E}/3R$
- d. $2\mathcal{E}/R$
- e. $\mathcal{E}/4R$

The next two questions continue from the previous page:



10. How much power is dissipated in this circuit if each resistor has resistance R ?

- a. ϵ^2 / R
- b. $2 \epsilon^2 / R$
- c. $R / 2 \epsilon^2$
- d. $\epsilon^2 / 4R$
- e. ϵ^2 / R

Handwritten solution for Q10:

$$P = \frac{V^2}{R_{eq}} \Rightarrow R$$

11. What is the electric potential difference $V_A - V_B$ if $\epsilon = 10 \text{ V}$, $R_1 = R_2 = 10 \Omega$, and $R_3 = R_4 = 5 \Omega$?

- a. 0.2 V
- b. 5 V
- c. 10 V
- d. 0 V
- e. 0.25 V

Handwritten solution for Q11:

$$V_A - V_B = V_3 - V_1 = I_3 R_3 - I_1 R_1$$

$$= \frac{\epsilon R_3}{R_3 + R_4} - \frac{\epsilon R_1}{R_1 + R_2}$$

$$= 0$$

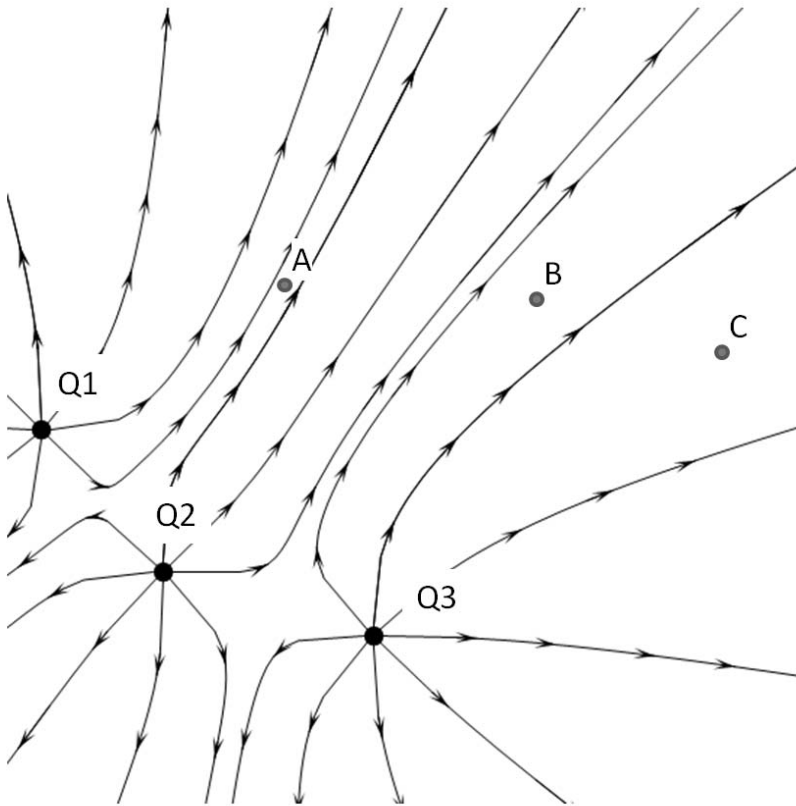
Handwritten boxed equations:

$$I_3 = \frac{\epsilon}{R_3 + R_4}$$

$$I_1 = \frac{\epsilon}{R_1 + R_2}$$

The next two questions pertain to the following diagram.

The following diagram has three charges, Q_1 , Q_2 , Q_3 , and three points in space, A, B, C.



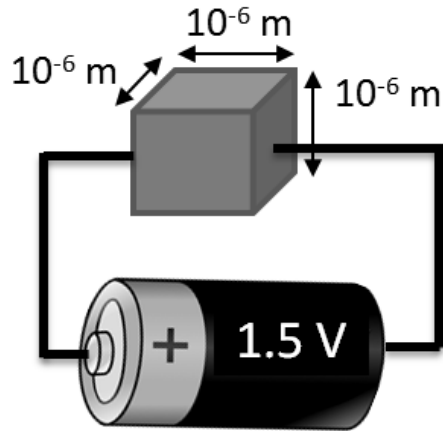
12. Where is the magnitude of the electric field strongest?

- a. A
- b. B
- c. C

13. What is true about the magnitude of the charges?

- a. $Q_1 > Q_2 > Q_3$
- b. $Q_1 = Q_2 = Q_3$
- c. $Q_3 > Q_2 > Q_1$

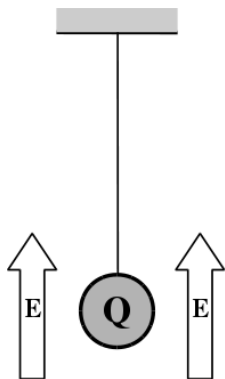
17. A resistor is created using a cube of carbon. The resistivity of carbon is $3.5 \times 10^{-5} \Omega \cdot \text{m}$. The length of each side of the cube is 10^{-6} m . The cube is hooked up to a 1.5 V battery as shown below. How much current flows through the cube?



- a. $4.3 \times 10^{10} \text{ A}$
- b. 0.043 A
- c. 23.3 A
- d. 0.1 A
- e. 1.5 A

The next two questions pertain to the following situation:

An insulating sphere of mass $m = 9.3$ kg and charge $Q = +4.6$ mC is hung on a light cotton string and then placed in an external electric field. The electric field is unknown in magnitude and points upward. The tension in the string is measured to be 76 N.



19. What is the magnitude of the external electric field?

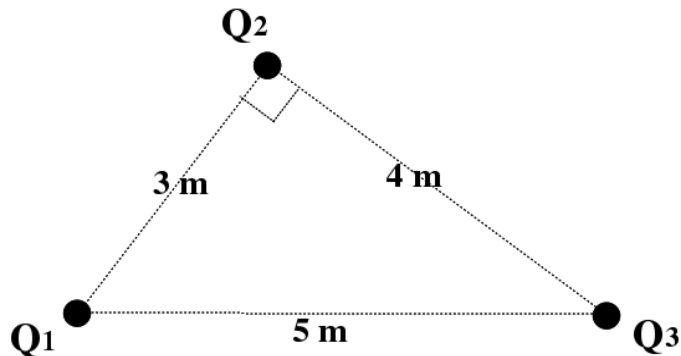
- a. $E = 480$ N/C
- b. $E = 630$ N/C
- c. $E = 1900$ N/C
- d. $E = 3300$ N/C
- e. $E = 5400$ N/C

20. Let the original tension in the string be T_0 . The charge Q is changed from $+4.6$ mC to -4.6 mC. What is the relationship between the new tension T_{new} and the original tension T_0 ?

- a. $T_{\text{new}} < T_0$
- b. $T_{\text{new}} = T_0$
- c. $T_{\text{new}} > T_0$

The next question pertains to the following situation:

Three charges are arranged in a right triangle, as shown. The three charges are $Q_1 = -3.4 \mu\text{C}$, $Q_2 = +5.6 \mu\text{C}$, and $Q_3 = -1.2 \mu\text{C}$.

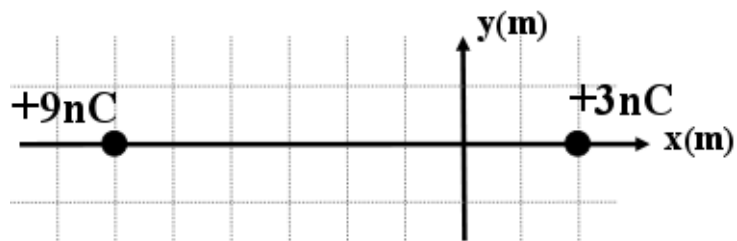


21. How much work was needed by an external force to assemble the three charges into the configuration above, assuming they started infinitely far away from each other?

- a. $W = -4.6 \times 10^{-2} \text{ J}$
- b. $W = -6.5 \times 10^{-2} \text{ J}$
- d. $W = +6.5 \times 10^{-2} \text{ J}$
- c. $W = +4.6 \times 10^{-2} \text{ J}$
- e. $W = +9.1 \times 10^{-2} \text{ J}$

The next two questions pertain to the following situation:

Two charges are located on the x-axis at positions -6 m and $+2$ m respectively. Each grid spacing is 1 meter.



22. What is the net electric field at the origin due to the two charges?

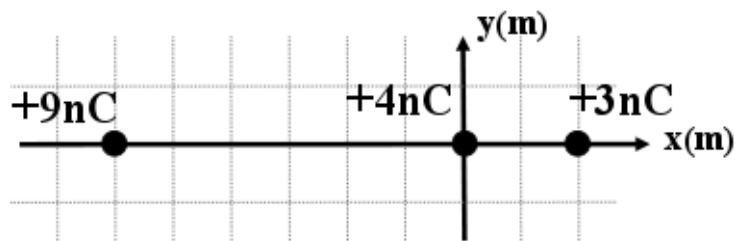
- a. -4.50 V/m
- b. -2.25 V/m
- c. $+9.00$ V/m

23. Calculate the electric potential at the origin due to the two charges.

- a. 3.9 V
- b. 4.6 V
- c. 12 V
- d. 27 V
- e. 32 V

The next two questions continue from the previous page:

Another charge with mass $m = 4.3 \times 10^{-17}$ kg is added to the configuration at the origin. The $+9\text{nC}$ and $+3\text{nC}$ charges are held stationary, while the 4nC charge is free to move.

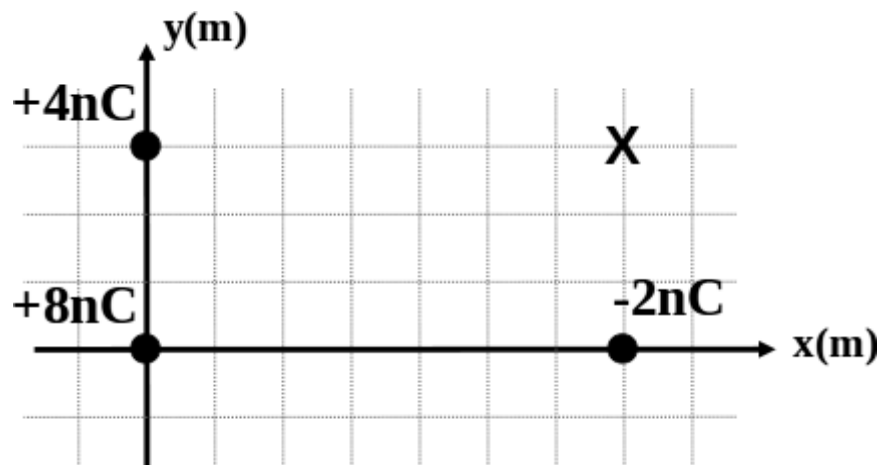


25. What is the speed of the 4nC charge after it is released and has traveled infinitely far away?

- a. $v = 9.3 \times 10^3$ m/s
- b. $v = 1.8 \times 10^4$ m/s
- c. $v = 3.7 \times 10^4$ m/s
- d. $v = 7.1 \times 10^4$ m/s
- e. $v = 8.5 \times 10^4$ m/s

The next question pertains to the following situation:

Three charges are located at $(0,0)$, $(7\text{ m},0)$, and $(0,3\text{ m})$, as shown below. Each grid spacing is 1 meter.



26. What is the net electric field at the point indicated at $(7\text{ m}, 3\text{ m})$?

- a. 0.76 V/m
- b. 2.4 V/m
- c. 5.9 V/m
- d. 12 V/m
- e. 39 V/m

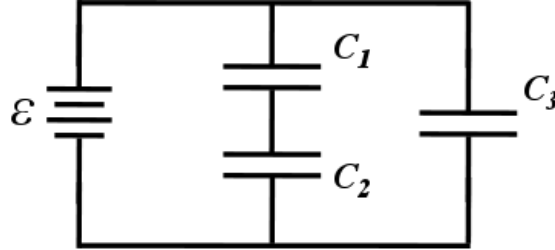
KEY

Exam 1 – Spring 2012

1. c
2. a
3. b
4. c
5. a
6. c
7. c
8. c
9. a
10. ae
11. d
12. a
13. b
14. b
15. c
16. a
17. b
18. abcde
19. d
20. c
21. b
22. a
23. d
24. b
25. d
26. b

The next three questions pertain to the following situation:

A system of capacitors, all of equal capacitance $C_1 = C_2 = C_3 = C$, is connected to an ideal battery of voltage $\mathcal{E} = 24 \text{ V}$.



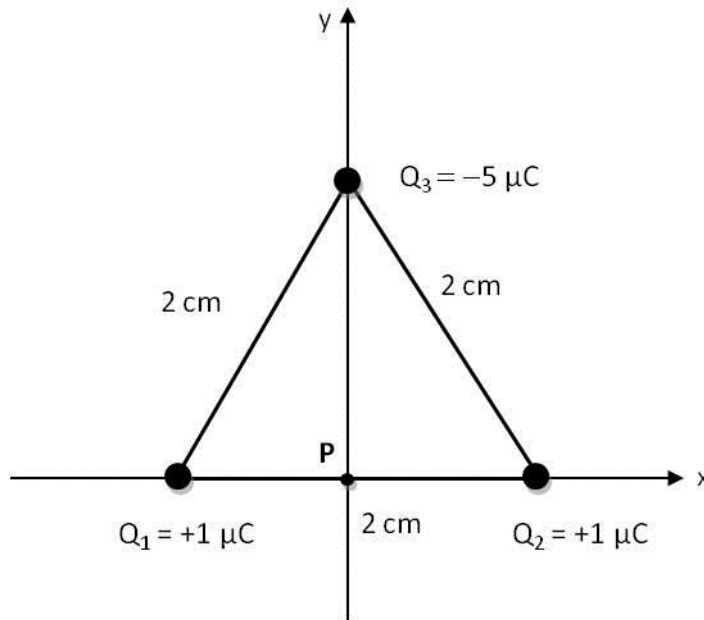
3. Calculate C given that the charge on capacitor C_2 is measured to be $Q_2 = 98 \text{ nC}$.
- $C = 43.9 \text{ nF}$
 - $C = 2.7 \text{ nF}$
 - $C = 312 \text{ nF}$
 - $C = 8.2 \text{ nF}$
 - $C = 126 \text{ nF}$

For the next two questions, assume that all of the capacitors have capacitance $C = 25 \mu\text{F}$ and that their charges are unknown.

4. What is Q_3 , the amount of charge collected on the capacitor C_3 ?
- $Q_3 = 150 \mu\text{C}$
 - $Q_3 = 300 \mu\text{C}$
 - $Q_3 = 600 \mu\text{C}$
5. How much energy U_{total} is stored in the capacitor network?
- $U_{total} = 0.9 \text{ mJ}$
 - $U_{total} = 3.2 \text{ mJ}$
 - $U_{total} = 10.8 \text{ mJ}$
 - $U_{total} = 58.2 \text{ mJ}$
 - $U_{total} = 36.8 \text{ mJ}$

The next five questions pertain to the following situation.

Three point charges are positioned on the vertices of an equilateral triangle as shown.



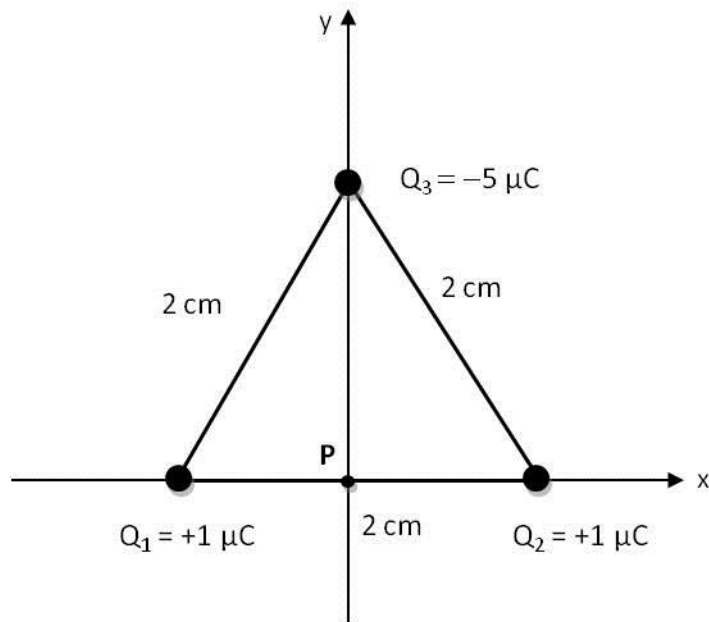
9. What is the direction of the electric field at the origin, **P**?

- a. Along the positive y-axis.
- b. Along the negative y-axis.

10. What is the magnitude of the electric field E at the origin, **P**?

- a. $E = 1.35 \times 10^7$ N/C
- b. $E = 5.39 \times 10^8$ N/C
- c. $E = 1.50 \times 10^8$ N/C
- d. $E = 1.12 \times 10^8$ N/C
- e. $E = 7.01 \times 10^8$ N/C

The next two questions continue from the previous page.



11. How much work W is required *by you* to assemble the three charges to this configuration?

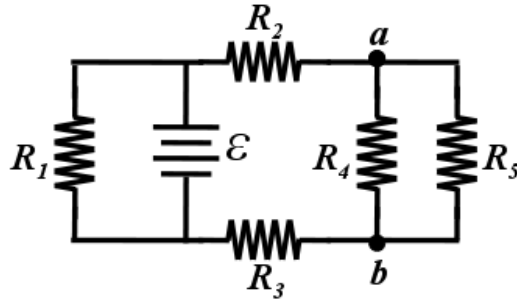
- a. $W = -0.0405 \text{ J}$
- b. $W = -4.05 \text{ J}$
- c. $W = 4.05 \text{ J}$
- d. $W = -202.3 \text{ J}$
- e. $W = 202.3 \text{ J}$

12. What is the electric potential V due to the three charges at origin, **P**?

- a. $V = -202.3 \text{ V}$
- b. $V = -2.34 \text{ V}$
- c. $V = 1.35 \text{ V}$
- d. $V = -1.35 \times 10^5 \text{ V}$
- e. $V = -7.98 \times 10^5 \text{ V}$

The next three questions pertain to the following situation:

An ideal battery of voltage $\mathcal{E} = 12 \text{ V}$ is connected to a circuit of resistors.



13. Assume all of the resistors have resistance R . What is the equivalent resistance, R_{eq} , for the circuit?

- $R_{eq} = 3R/2$
- $R_{eq} = 5R$
- $R_{eq} = 5R/7$
- $R_{eq} = 4R/3$
- $R_{eq} = 13R/9$

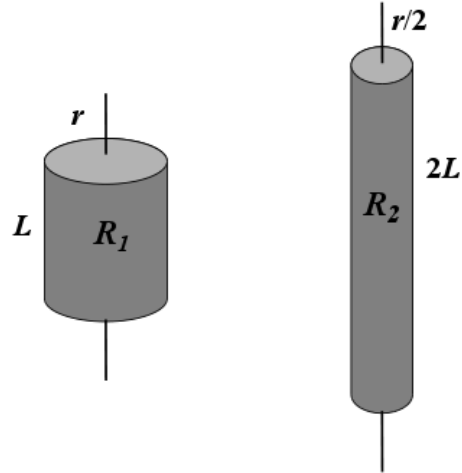
14. If the resistance of each resistor $R = 75 \Omega$, what is P_1 , the power dissipated by resistor R_1 ?

- $P_1 = 1.9 \text{ W}$
- $P_1 = 9.0 \text{ W}$
- $P_1 = 5.7 \text{ W}$

15. What is the voltage V_{ab} difference between points a and b , as labeled on the circuit?

- $V_{ab} = 2.4 \text{ V}$
- $V_{ab} = 18.2 \text{ V}$
- $V_{ab} = 6.0 \text{ V}$
- $V_{ab} = 12.0 \text{ V}$
- $V_{ab} = 4.8 \text{ V}$

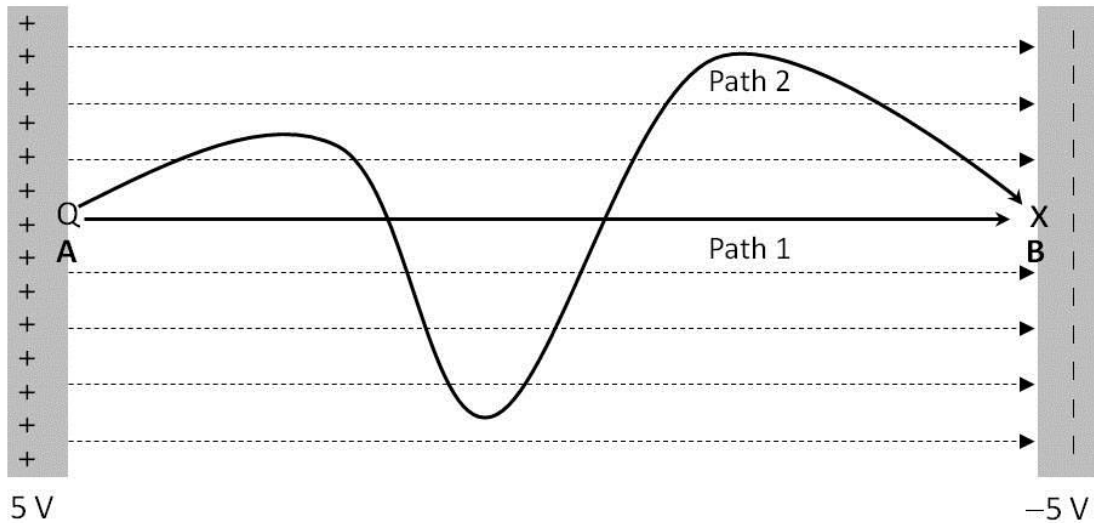
16. Two resistors are created using copper, which has resistivity $\rho = 1.72 \times 10^{-8} \Omega \cdot \text{m}$. The first resistor has radius r and length L . The second resistor has radius $r/2$ and length $2L$. What is the ratio of the second resistor's resistance R_2 to that of the first resistor's resistance R_1 ?



- a. $R_2/R_1 = 1/4$
- b. $R_2/R_1 = 1/2$
- c. $R_2/R_1 = 2$
- d. $R_2/R_1 = 8$
- e. $R_2/R_1 = 16$

The next two questions pertain to the following situation.

A uniform electric field is generated by two parallel plate electrodes, positive and negative, respectively, as shown. The dashed lines indicate the electric field. The electric potential at the positive and the negative electrode is 5 V and -5 V, respectively. Consider a charge $Q = +3$ mC with mass of 1 mg.



17. Imagine that you move the charge Q from point **A** to point **B** along the two paths shown. Let W_1 and W_2 be the work done *by the electric field* following Path 1 and Path 2, respectively. What is the relationship between W_1 and W_2 ?

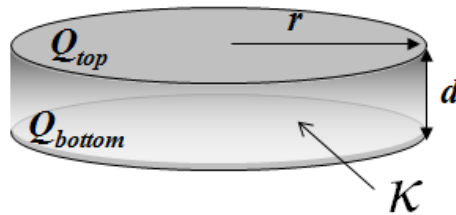
- $W_1 > W_2$
- $W_1 < W_2$
- $W_1 = W_2$

18. If the charge Q is released freely at **A**, what is its speed, v , when arriving at **B**?

- Not enough information is given.
- $v = 7.75$ m/s
- $v = 5.48$ m/s
- $v = 173$ m/s
- $v = 245$ m/s

The next two questions pertain to the following situation:

A capacitor is created by placing two circular metal plates of radius 2 mm a distance 5 μm apart. A material of dielectric constant $\mathcal{K} = 2.5$ is placed between the plates. The capacitor is then charged by placing a charge $Q_{top} = +3 \text{ nC}$ on the top plate and $Q_{bottom} = -3 \text{ nC}$ on the bottom plate. After charging, the capacitor is disconnected from all other elements, such as wires or a battery.



19. What is the voltage difference V measured between the two plates of this capacitor?

- a. $V = 15 \text{ V}$
- b. $V = 54 \text{ V}$
- c. $V = 95 \text{ V}$
- d. $V = 65 \text{ V}$
- e. $V = 225 \text{ V}$

20. The plates are then pulled apart so that the distance between them is increased from 5 μm to 20 μm . How does the new charge on the top plate $Q_{top,new}$ compare to the original charge on the top plate Q_{top} ?

- a. $Q_{top,new} < Q_{top}$
- b. $Q_{top,new} > Q_{top}$
- c. $Q_{top,new} = Q_{top}$

KEY

Exam 1 – Spring 2013

1. b
2. a
3. d
4. c
5. c
6. c
7. c
8. c
9. a
10. c
11. b
12. e
13. c
14. a
15. a
16. d
17. c
18. e
19. b
20. c
21. c
22. e
23. b
24. a
25. c
26. b
27. b