Last Name:_____First Name_____Network-ID_____

Discussion Section:_____Discussion TA Name:_____

Turn off your cell phone and put it out of sight.
Keep your calculator on your own desk. Calculators cannot be shared.
This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil. Do not use a mechanical pencil or pen. Darken each circle completely, but stay within the boundary. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner. Be especially careful that your mark covers the **center** of its circle.

2. **This Exam Booklet is Version A**. Mark the **A** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**

3. Print your **NETWORK ID** in the designated spaces at the *right* side of the answer sheet, starting in the left most column, then **mark the corresponding circle** below each character. If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero. If and only if there is a hyphen "-" in your NetID, mark the hyphen circle at the bottom of the column. When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.

4. Print **YOUR LAST NAME** in the designated spaces at the *left* side of the answer sheet, then mark the corresponding circle below each letter. Do the same for your **FIRST NAME INITIAL**.

5. Do not write in or mark the circles in any of the other boxes (STUDENT NUMBER, DATE, SECTION, SCORES, SPECIAL CODE).

6. Sign your name **(DO NOT PRINT)** on the **STUDENT SIGNATURE** *line*.

7. On the **SECTION** *line*, print your **DISCUSSION SECTION**. You need not fill in the COURSE or INSTRUCTOR lines.

*Before starting work, check to make sure that your test booklet is complete. You should have 18 **numbered pages** plus three Formula Sheets.*

Academic Integrity—**Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the University.**

Exam Grading Policy—

The exam is worth a total of **xxx** points, composed of three types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.

(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer,
you earn **2** points.
(d) If you mark no answers, or more than *three*, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **3** points.
(b) If you mark a wrong answer or no answers, you earn **0** points.

**MC2:** *multiple-choice-two-answer questions, each worth 2 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer,
you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

Some helpful information:
- A reminder about prefixes: p (pico) = 10^{-12}; n (nano) = 10^{-9}; μ (micro) = 10^{-6};
  m (milli) = 10^{-3}; k (kilo) = 10^{+3}; M or Meg (mega) = 10^{+6}; G or Gig (giga) = 10^{+9}.

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

= C/3

A
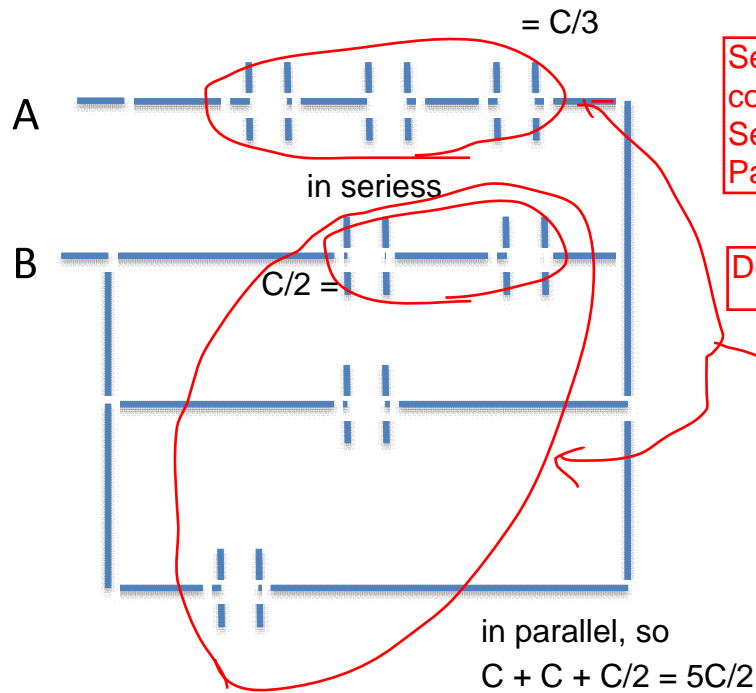
Series and parallel connections
Series 1/C = ¥sum 1/Ci
Parallel C = ¥sum Ci

in seriess

B

C/2 =

Do it step by step

No these two blocks are in series

in parallel, so
C + C + C/2 = 5C/2

C = (5C/2) (C/3)/)5C/2 + C/3)
= (5C/6)/((15+2)/6)
= 5C/17

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

Notice that if
1/C = 1/A + 1/B,
then
C = AB/(A+B)

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

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: $C_1 = 10$ μF, $C_2 = 20$ μF, $C_3 = 30$ μF, $C_4 = 40$ μF, $C_5 = 50$ μF, $C_6 = 60$ μF, and $\mathcal{E} = 12$ Volts. The points A and B are labeled on the diagram.

From the local structures, handle them step by step.

C_2

C_3

C_5

$\mathcal{E}$

C_1

C_4

C_6

= (50x60)/(110)
= 300/11

=1200/70
= 120/7

A

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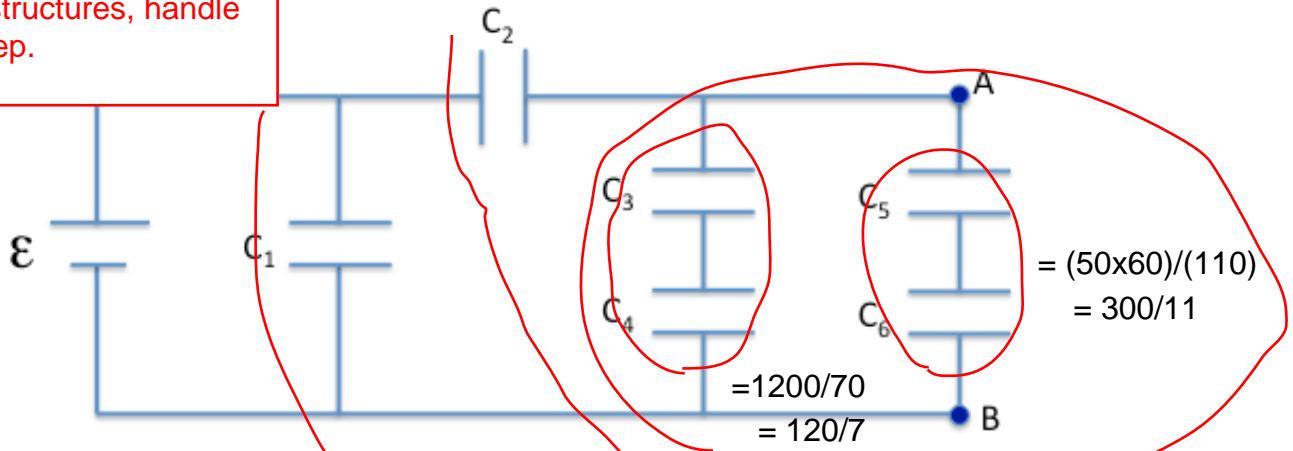
2. What is the equivalent capacitance of this entire network?

a. $C_{eq} = $ 23.8 μF
b. $C_{eq} = 123.5$μF
c. $C_{eq} = $ 52.8 μF
d. $C_{eq} = 100.1$ μF
e. $C_{eq} = $ 65.9 μF

= 10 + 13.79 ¥muC

= 120/7 + 300/11
= (1320+2100)/77 = 3420/77
in series
= (20 x 3420/77)/(20 + 3420/77)
= 68400/4960 = 13.79

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

a. $Q_2 = $ 95.1 μC
b. $Q_2 = 120.0$ μC
c. $Q_2 = 131.0$ μC
d. $Q_2 = $ 85.3 μC
e. $Q_2 = 201.3$ μC

The voltage across the capacitor is 12V, so
Q = 12C1 = 120 ¥muC

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.

Note that the voltage across C1 does not change at all.

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.
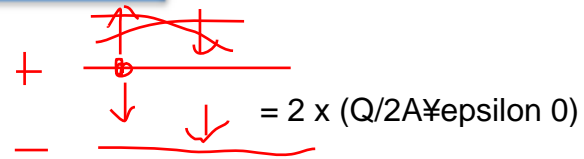
Each Q produces
Q/¥epsilon0 field lines

capacitor

$\mathcal{E}$

5. What is the electric field, E, between the plates? $= 2 \times (Q/2A¥epsilon\ 0)$

a. E = 2.33 x 10³ N/C
b. E = 1.54 x 10³ N/C
c. E = 3.14 x 10⁴ N/C
d. E = 5.98 x 10³ N/C
e. E = 6.79 x 10⁴ N/C

E = Q/A¥epsilon0
 = 10 x 10^{-12}/(0.022^2 x 8.85 x 10^{-12})
 = 2334.6 x 10^{-12+12} = 2.33 x 10^3 N/C

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.

capacitor
with dielectric

$\mathcal{E}$
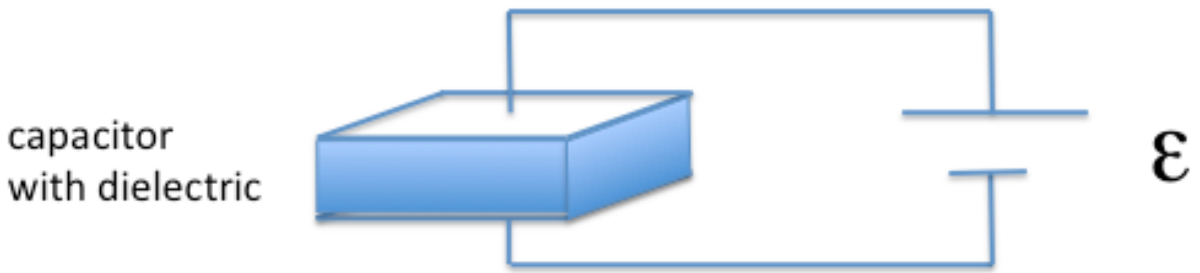
U = (1/2)CV^2

The new stored energy of the capacitor U_2 is

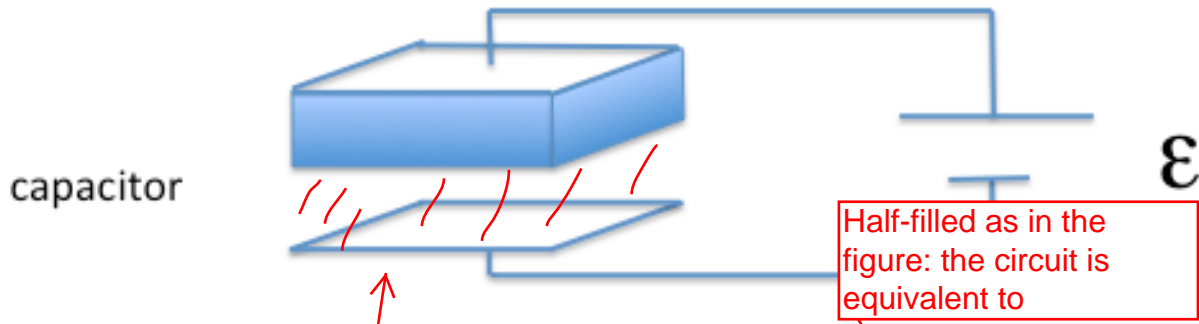a. the same as U_1.
b. less than U_1.
c. larger than U_1.

In this case V does not change, but C -> KC, so
      U2 = KU1 = 2 U1

The next question continues from the previous page.

The question is ambiguous.

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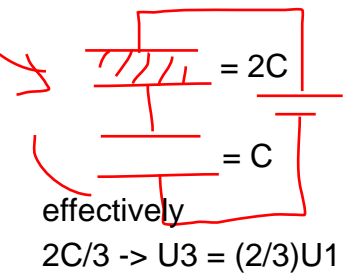
capacitor

ε

Half-filled as in the figure: the circuit is equivalent to
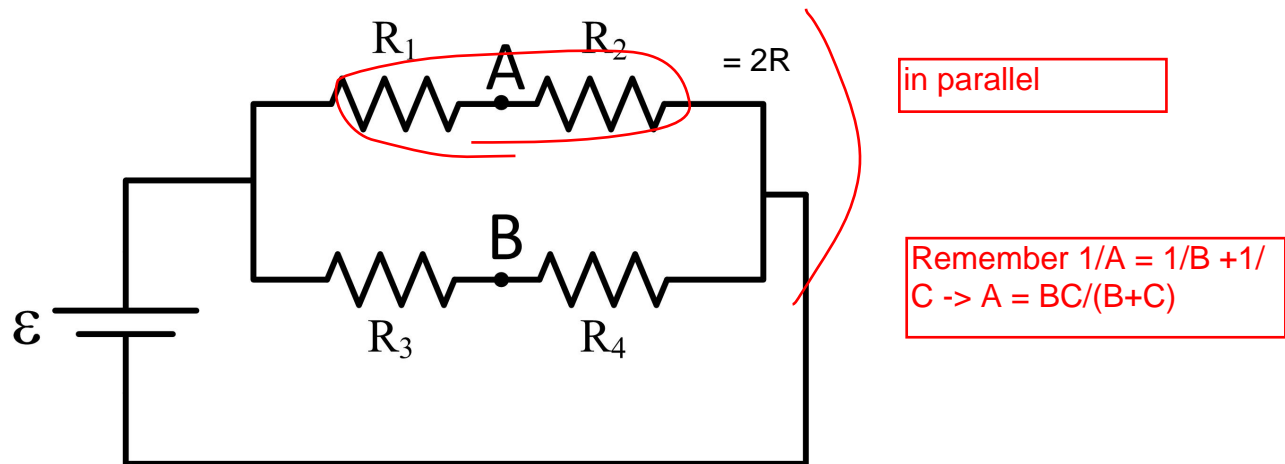
$= 2C$

$= C$

effectively

2C/3 -> U3 = (2/3)U1

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. $U_3 = 2/3\ U_1$

If the gap is totally filled with the dielectric material, then, C does not change, so
U3 = U1

The next four questions refer to the following circuit:

R_1 A R_2 = 2R   in parallel

B

R_3 R_4 Remember 1/A = 1/B +1/C -> A = BC/(B+C)

ε

8. If all four resistors have resistance R, what is the total equivalent resistance for this circuit?
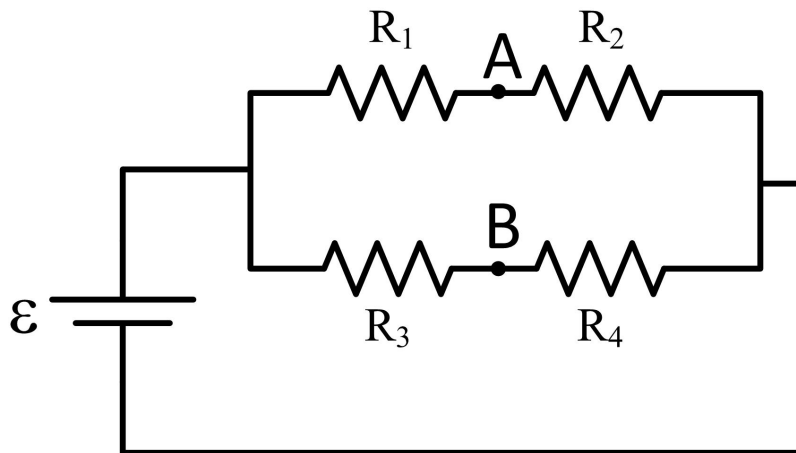
a. 4R
b. 2R
c. R   (2R)(2R)/(2R + 2R) = R
d. R/4
e. R/2

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

a. ε / R   YES, but the problem is not good due to the propagation of error from 8.
b. 2 R / ε
c. ε / 3R
d. 2 ε / R
e. ε / 4R

The next two questions continue from the previous page:

R_1 A R_2

B

R_3 R_4

ε

P = V^2/R

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

a. ε^2 / R
b. $2\,\varepsilon^2 / R$
c. $R/ 2\,\varepsilon^2$
d. $\varepsilon^2 / 4R$
e. ε^2/R

YES, but again this is not a
good problem to ask, since you
need the answer to 8.

11. What is the electric potential difference V_A-V_B if ε=10 V, R_1=R_2=10 Ω, and R_3=R_4=5 Ω?

Along each branch voltage drop is proportional to R, so for
both the branches, A, B are mid point = 5 V.

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

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.
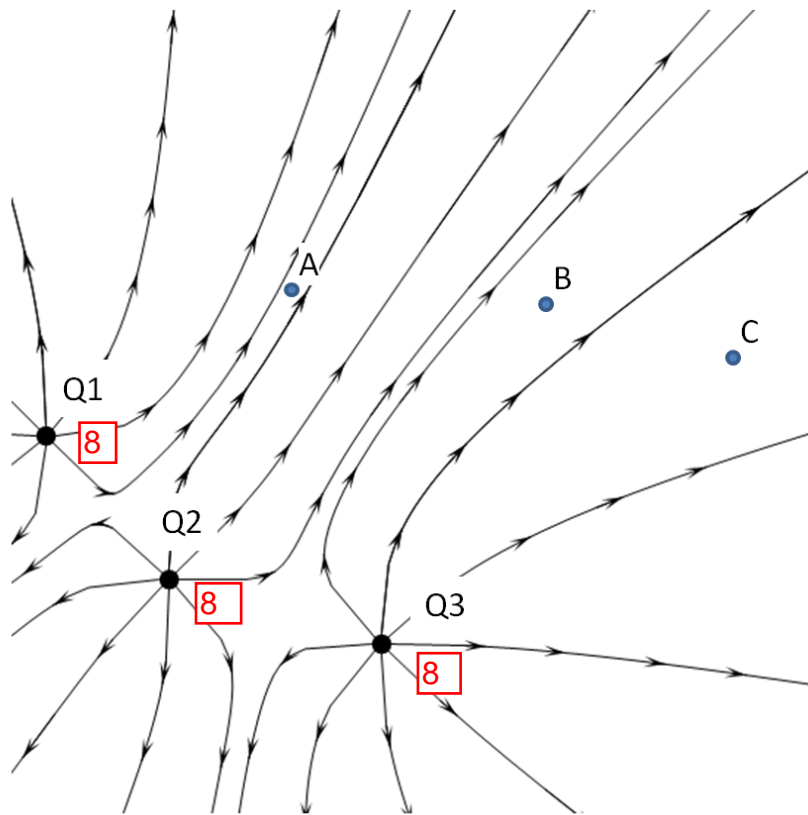
Field line density indicates the intensity of E.

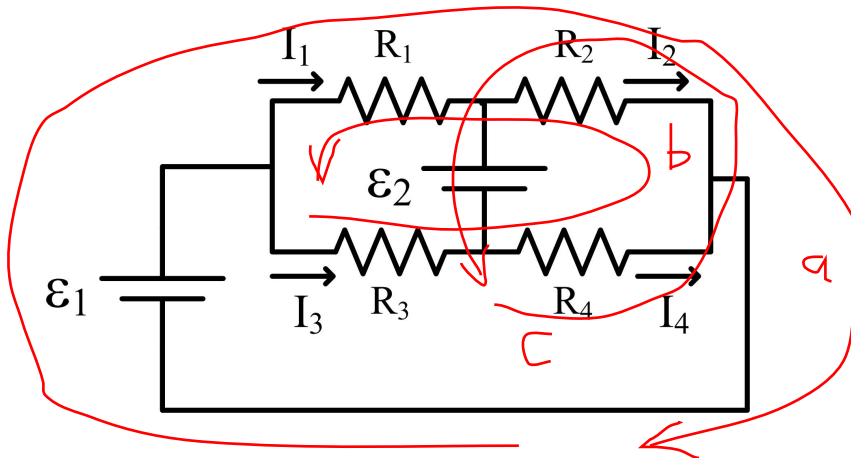12. Where is the magnitude of the electric field strongest?

a. A
b. B
c. C

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

a. $Q_1 > Q_2 > Q_3$
b. $Q_1 = Q_2 = Q_3$ $8 = 8 = 8$!
c. $Q_3 > Q_2 > Q_1$

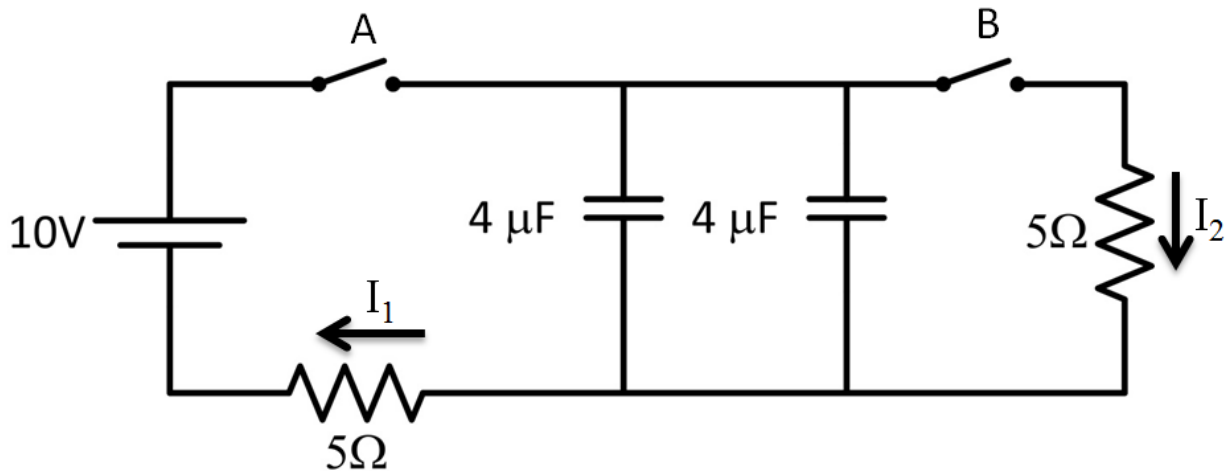Q produces $Q/\yen epsilo0$ field lines. All 8 in this figure.

14. What is a valid Kirchhoff loop rule for the circuit shown above?

a. $\varepsilon_1 + I_1 R_1 - I_2 R_2 = 0$

b. $I_4 R_4 + I_3 R_3 - I_1 R_1 - I_2 R_2 = 0$

c. $-\varepsilon_2 - I_2 R_2 + I_4 R_4 = 0$

loop a: E1 - I1R1 - I2R2 = 0
up   down down

loop b: -I4R4 + I2R2 + I1R1 - I3R3 = 0
down   up   up   down

loop c: -I4R4 + I2R2 - E2 = 0
down up down

The next two questions pertain to the circuit shown below:

15. Switch B is opened. What is the current I_1 if switch A is left closed for a long time?

a. 2 A
b. 0.5 A
c. 0 A

Notice that the capacitors are full, so the top plates have 10V, and there is no voltage drop across the resistor. 0 A.

16. Switch B is opened and switch A is left closed for a long time. Then switch A is opened and switch B is closed. What is the current I_2 immediately after switch B is closed?
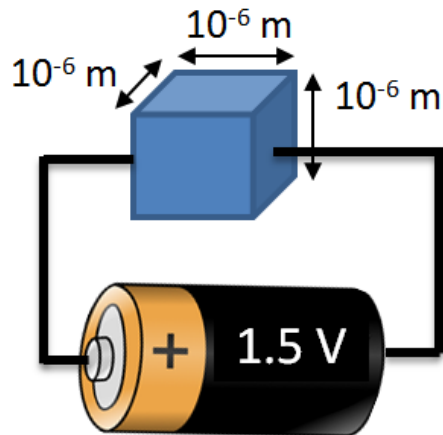
a. 2 A
b. 0.5 A
c. 0 A

Initially, the capacitors are full, so the top plates have 10 V. The circuit is equivalent to

10V   5 ohms

I2 = 10/5 = 2 A.
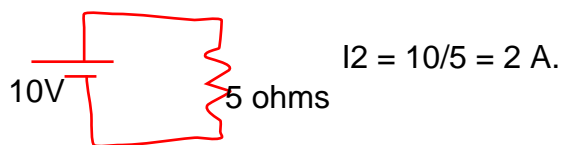
17. A resistor is created using a cube of carbon. The resistivity of carbon is 3.5×10^{-5} Ω m. The length of each side of the cube is 10^{-6} m. The cube is hooked up to a 1.5 V battery as shown below. How much current flows through the cube?
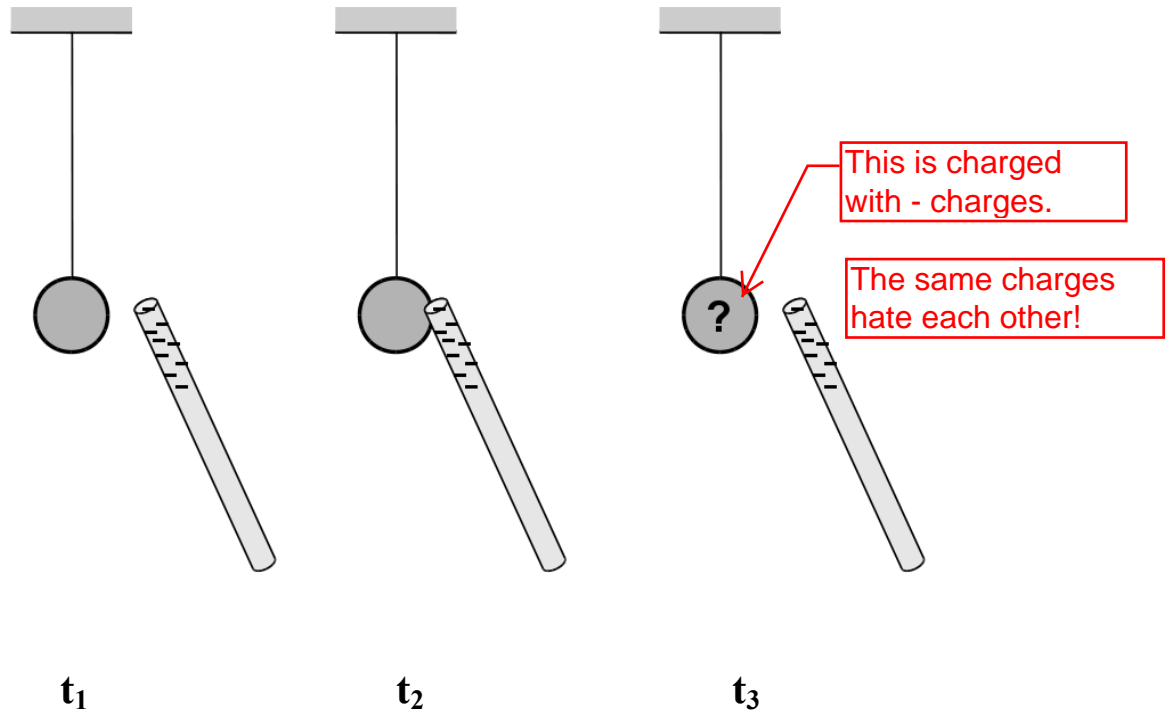
R = ¥rho L/A

10⁻⁶ m

10⁻⁶ m

10⁻⁶ m

1.5 V

R = ¥rho L/L^2 = ¥rho/L
  = 3.5 x 10^{-5}/10^{-6} = 35 ohms
I = 1.5 /35 = 0.0429 A

a. 4.3×10^{10} A
b. 0.043 A
c. 23.3 A
d. 0.1 A
e. 1.5 A

18. A perfectly conducting sphere is hung from a light cotton string attached to a fixed support (t_1). A conducting rod with a net negative charge is made to touch the sphere (t_2) and then moved away.


This is charged with - charges.

The same charges hate each other!

t_1 t_2 t_3

Which direction does the insulating sphere move at time t3, when the rod is held nearby?

a. toward the rod
b. away from the rod
c. does not move

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.

tension

electric force

E   Q   E
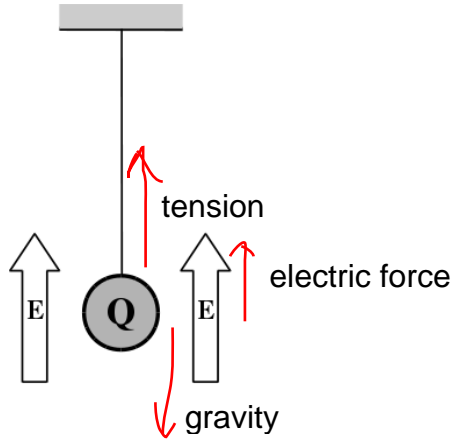
gravity

There are three forces, gravity, electric force, and the tension. The force balance implies

tension + electric force = gravity = mg

or

76 + 4.6 x 10^{-3}E = 9.3 x 9.8.

That is,

4.6x10^{-3}E = 91.14 - 76 = 15.14 N

E = 3.29 x 10^3 N/C

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?
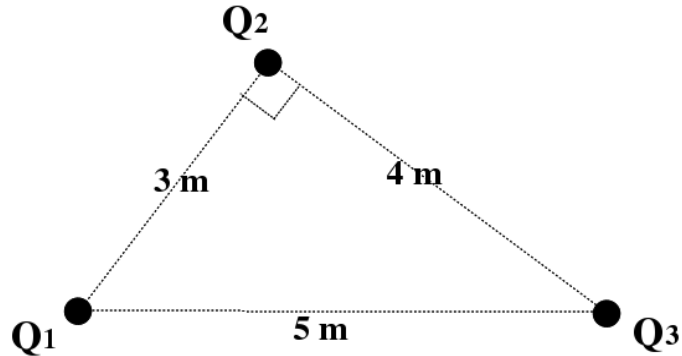
Now   Tnew > Told, obviously.

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

new electric force

The next question pertains to the following situation:

Three charges are arranged in a right triangle, as shown. The three charges are $Q_1 = -3.4$ μC, $Q_2 = +5.6$ μC, and $Q_3 = -1.2$ μC.

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?
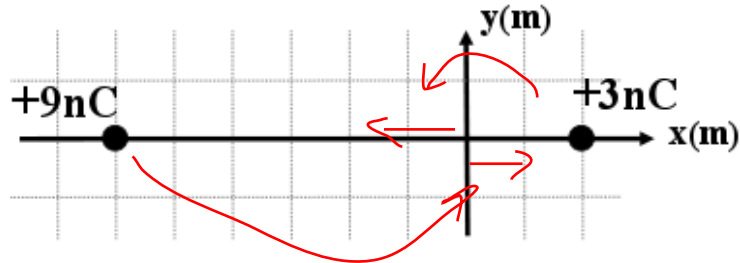
a. $W = -4.6 \times 10^{-2}$ J

b. $W = -6.5 \times 10^{-2}$ J

d. $W = +6.5 \times 10^{-2}$ J

c. $W = +4.6 \times 10^{-2}$ J

e. $W = +9.1 \times 10^{-2}$ J

Superposition principle

V = k(Q1Q2/3 + Q2Q3/4 + Q3Q1/5)

  = (9x10^9) [(-3.4)(5.6)/3 + (5.6)(-1.2)/4 + (-1.2)(-3.4)/5] x 10^{-12}

  = - 64.9 x 10^{-3} = -6.5 x 10^{-2} 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

$k|Q|/r^2$ is the magnitude of the electric field.

b. −2.25 V/m

superposition principle

c. +9.00 V/m

$$Ex = + (9 \times 10^9) (9 \times 10^{-9}))/6^2 - (9 \times 10^9) (3 \times 10^{-9}/2^2$$
$$= 2.25 - 6.75 = - 4.5 \text{ V/m}$$

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

a. 3.9 V

kQ/r is the electric potential.

b. 4.6 V

superposition principle

c. 12 V

d. 27 V

e. 32 V
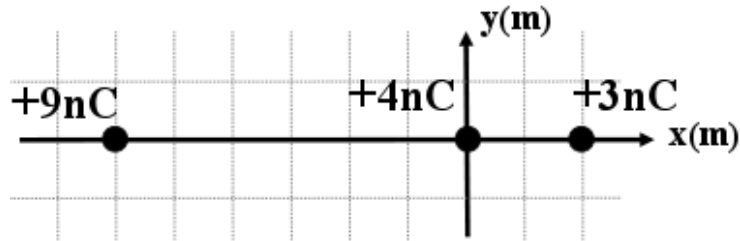
$$V = (9 \times 10^9) (9 \times 10^{-9}))/6 + (9 \times 10^9) (3 \times 10^{-9}/2$$
$$= 13.5 + 13.5 = 27 \text{ V}.$$

The next two questions continues from the previous page:

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

24. What is the magnitude of the force on the 4 nC charge?

a. 8 x 10^{-9} N
b. 1.8 x 10^{-8} N
c. 3.9 x 10^{-8} N

Since |E| = 4.5 N/C as calculated in 22,
|F| = 4.5 x 4 x 10^{-9} = 18 x 10^{-9} N

Bad exam problem due to error
propagation possibility.

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

a. v = 9.3 x 10^3 m/s
b. v = 1.8 x 10^4 m/s
c. v = 3.7 x 10^4 m/s
d. v = 7.2 x 10^4 m/s
e. v = 8.5 x 10^4 m/s

Its initial potential energy is QV = 27 x 4 x 10^{-9} J.
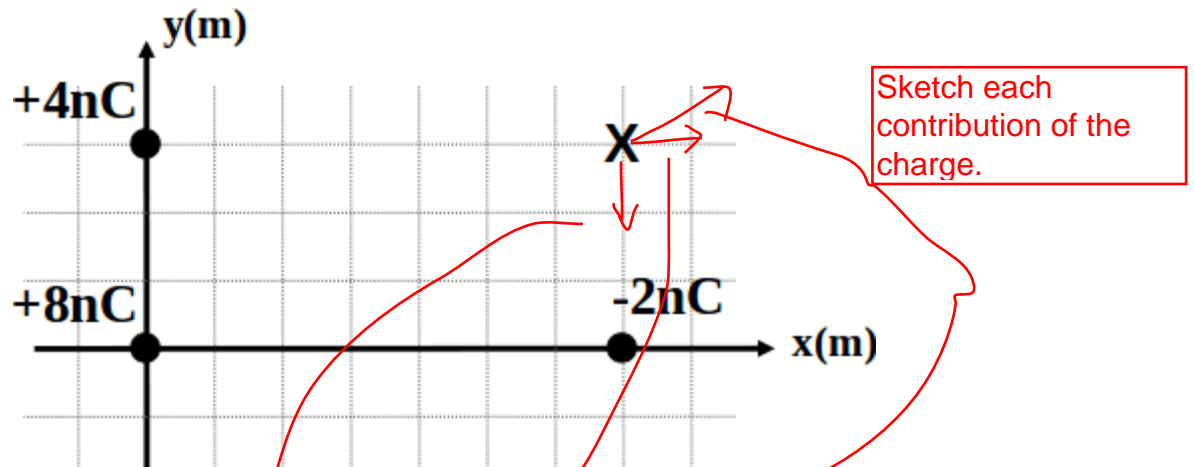The energy conservation tells us
          (1/2)mv^2 = 108 x 10^{-9}
or
          v^2 = (216x 10^{-9}/4.2 x 10^{-17}) = 51.4 x 10^8
That is v = 7.17 x 10^4 m.s

The next two questions pertain to the following situation:

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

It seems there is no short cut to answer this question.

+4nC

X

Sketch each contribution of the charge.

+8nC

-2nC

y(m)

x(m)

26. What is the net electric field at the point indicated at (7 m, 3 m)?

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

$= (9 \times 10^{9})(2 \times 10^{-9})/3^2 = 2$ V/m

x comp $= (9 \times 10^{9})(8 \times 10^{-9})/(3^2 + 7^2) \times (7/\sqrt{58}) = 1.14$
y comp $= 1.24 \times (3/\sqrt{58}) = 0.488$

$(9 \times 10^{9})(4 \times 10^{-9})/7^2 = 0.735$

Therefore E = 1.14 + 0.735, -2 + 0.488) = (1.875, -1.512).
Hence, |E| = $\sqrt{1.875^2 + 1.512^2}$ = 2.409 V/m.

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