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. You may find the version of **This Exam Booklet at the top of page 2**. Mark the version 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. Print your UIN# in the STUDENT NUMBER designated spaces and mark the corresponding circles. You need not write in or mark the circles in the SECTION box.

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 14 ***numbered pages*** *plus three (3) 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.**

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!**

Exam Grading Policy—

The exam is worth a total of **121** 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.

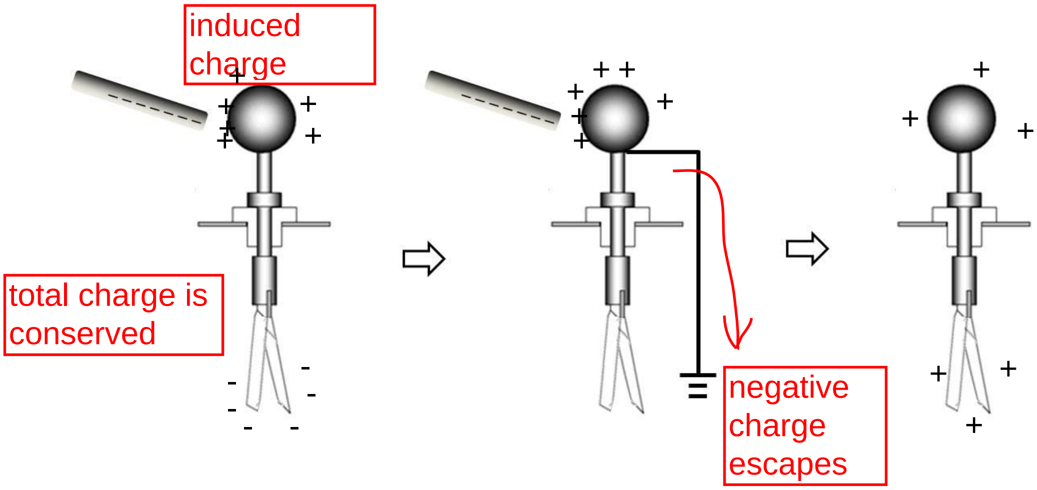
MC2: *multiple-choice-two-answer questions, each worth 2 points.*
No partial credit.

(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:

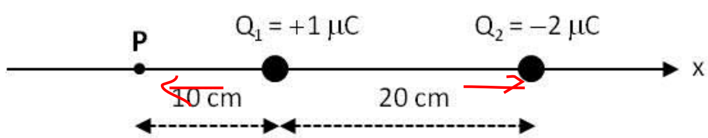
- A reminder about prefixes: p (pico) = 10^{-12}; n (nano) = 10^{-9}; μ (micro) = 10^{-6}; m (milli) = 10^{-3}; k (kilo) = 10^{+3}; M or Meg (mega) = 10^{+6}; G or Gig (giga) = 10^{+9}.

1. A negatively charged rod is brought near (but does not touch) an electroscope as shown. Then, the scope is briefly grounded. Regarding the whole sequence of three steps, which statement is NOT true?



a. Negative charges will flow from the scope to the ground.
b. Negative charges will be induced on the scope when the rod is moved away.
c. The leaves will repel each other when the rod is moved away.

2. Two point charges are placed on the *x*-axis as shown. If a positive charge is brought to the point **P**, what is the direction of the net electric force felt by this charge?

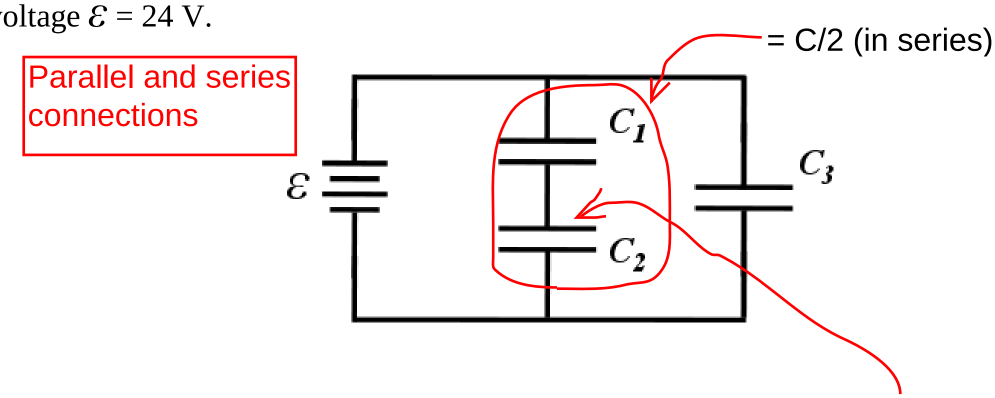


a. Along the negative *x*-axis.
b. Along the positive *x*-axis.
c. It depends on the magnitude of the positive charge at point **P**.

Let us compute the x-component
Q1: -kQ1/(0.1^1) = -(9 x 10^9) (1 x 10^{-6})/(0.1^2) = -9 x 10^{9 - 6 +2} = - 9 x 10^{5} N/C
Q2: +kQ2/(0.3^2) = (9 x 10^9) (2 x 10^{-6})/(0.3^2) = 2 x 10^{9 - 6 + 2} = 2 x 10^5 N/C.
The sum is -7 x 10^5 N/C.

The next three questions pertain to the following situation:

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



3. Calculate C given that the charge on capacitor C_2 is measured to be Q_2 = 98 nC.

a. C = 43.9 nF
b. C = 2.7 nF
c. C = 312 nF
d. C = 8.2 nF
e. C = 126 nF

Since C1 = C2 = C, the voltage across C2 is E/2 = 12 V.
Q2 = VC2 -> C = Q2/V = 98 x 10^{-9}/12 = 8.17 x 10^{-9}

4. Now let all of the capacitors have value C = 25 μF and unknown charge. What is Q_3, the amount of charge collected on the capacitor C_3?

a. Q_3 = 150 μC
b. Q_3 = 300 μC
c. Q_3 = 600 μC

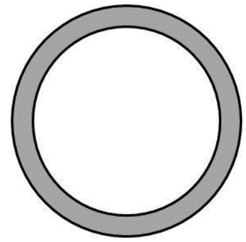
The voltage across C3 is 24 V, so Q3 = 24 x (25 x10^{-6})
= 600 x 10^{-6} C

5. Again the capacitors have value C = 25 μF and unknown charge. How much energy U_{total} is stored in the capacitor network?

a. U_{total} = 0.9 mJ
b. U_{total} = 3.2 mJ
c. U_{total} = 10.8 mJ
d. U_{total} = 58.2 mJ
e. U_{total} = 36.8 mJ

The total capacitance is
Ctot = C + C/2 = 3C2 (in parallel) = 37.5 ¥muF
Therefore,
Utot = (1/2) CtotV^2 = (1/2)(37.5 x 10^{-6}) x 24^2
= 10800 x10^{-6} = 10.8 x 10^{-3} J

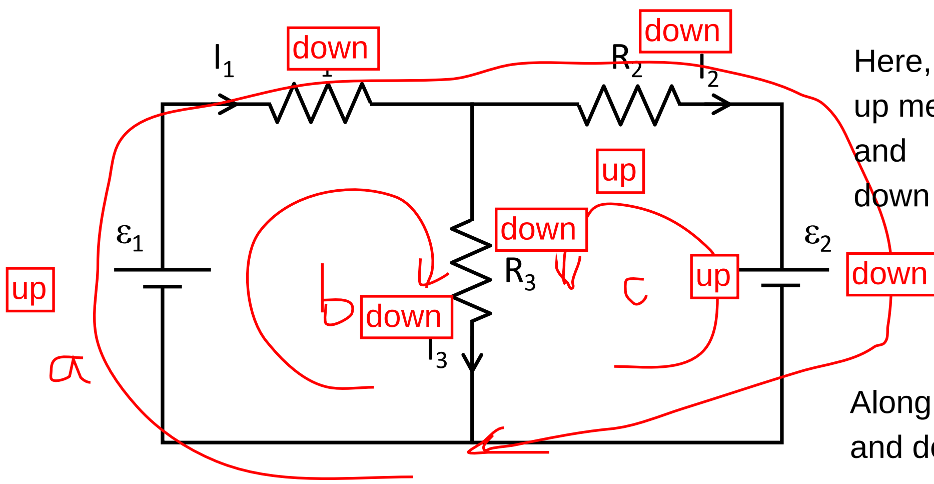
6. Consider an uncharged spherical conducting shell as shown. If charges are transferred to it, which statement is TRUE regarding their behavior?



a. They will be distributed uniformly throughout the conductor.
b. They will spread on the inner surface.
c. They will spread on the outer surface.

The same charges wishe to be as far away as possible from each other.

7. Consider the circuit below. Which of the following equations is ***incorrect***?



Here,
up means voltage goes up and
down means V goes down.

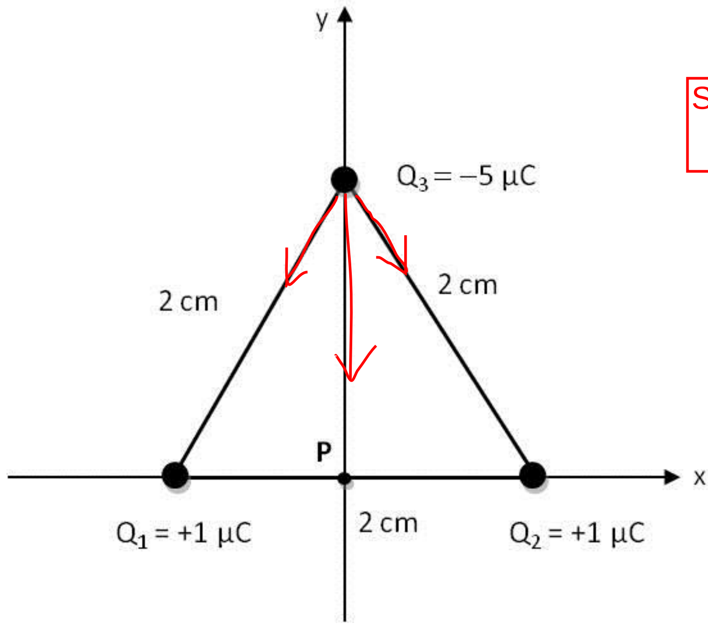
Along a loop up means + and down -.

a. $\mathcal{E}_1 - \mathcal{E}_2 - I_1R_1 - I_2R_2 = 0$
b. $\mathcal{E}_1 - I_1R_1 - I_3R_3 = 0$
c. $\mathcal{E}_2 - I_2R_2 - I_3R_3 = 0$

loop a: E1 - I1R1 - I2R2 - E2 = 0
loop b: E1 - I1R1 - I3R3 = 0
loop c: E2 + I2R2 - I3R3 = 0

The next five questions pertain to the following situation.

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



Sketch the forces

8. What is the magnitude of the net electric force F on the charge Q_3?

a. $F = 3.89$ N
b. $F = 112$ N
c. $F = 195$ N

The magnitude of the force due to Q1 is
|F| = kQ1Q2/(0.02^2) = (9x10^9) (1x10^{-6}) (5x10^{-6})/(0.02^2)
= 11.25 x 10^{9 - 6 - 6 + 4} = 11.25 x 10^{1} = 112.5 N.
Therefore., the y component of the total force (= total force) is
112.5 cos 30deg x 2 = 112.5 x ¥sqrt{3} = 194.9 N

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.

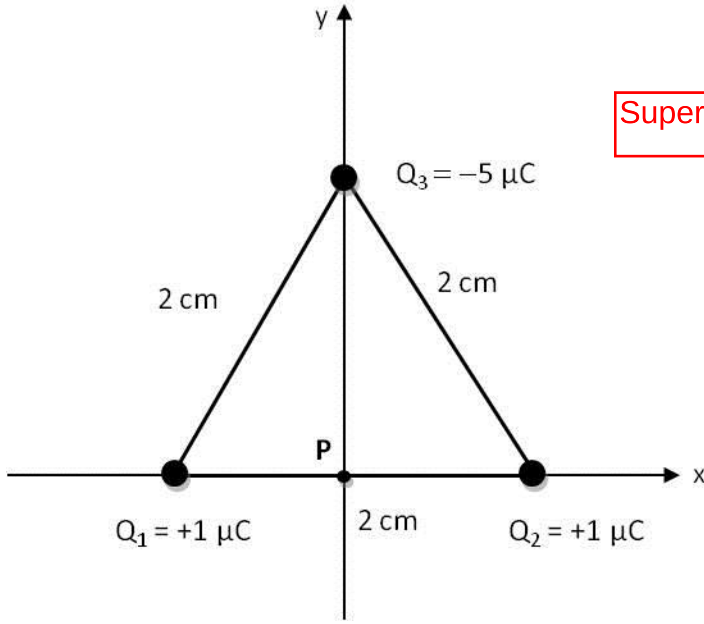
At the origin Q1 and Q2 kill each other, so the force is only due to Q3. Upward.

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

a. $E = 1.35\times10^{7}$ N/C
b. $E = 5.39\times10^{8}$ N/C
c. $E = 1.50\times10^{8}$ N/C
d. $E = 1.12\times10^{8}$ N/C
e. $E = 7.01\times10^{8}$ N/C

|E| = kQ3/(0.02 cos 30)^2
= (9x10^9) (5 x 10^{-6})/ (¥sqrt{3} x 10^{-2})^2
= 15 x 10^{9 - 6 + 4} = 15 x 10^{7} N/C

The next two questions continue from the previous page.



Superposition principle

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

a. $W = -0.0405$ J
b. $W = -4.05$ J
c. $W = 4.05$ J
d. $W = -202.3$ J
e. $W = 202.3$ J

If he total potential energy is U, the work needed to make this assembly is U.
U = (k/0.02)[Q1Q3 + Q3Q2 + Q2Q1]
= (9x10^9/0.02)[- 5 - 5 + 1] x 10^{-12}
= -40.5 x 10^{9 -12 + 2} = - 4.05 J.

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

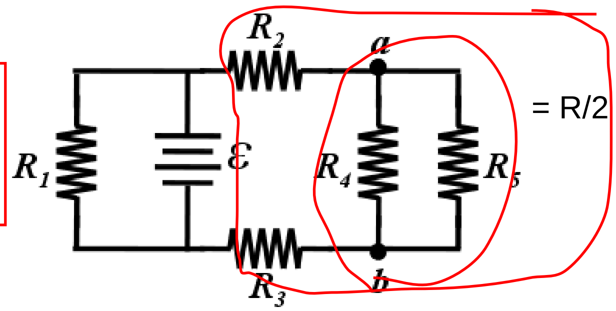
a. $V = -202.3$ V
b. $V = -2.34$ V
c. $V = 1.35$ V
d. $V = -1.35\times10^5$ V
e. $V = -7.98\times10^5$ V

V = k [Q1/1cm + Q2/1cm - Q3/¥sqrt{3}cm]
= (9x10^9) [1 + 1 - 5/¥sqrt{3}] (1x10^{-6})/(0.01)
= -7.98 x 10^{9 - 6 +2} = -7.98 x 10^5 V.

The next three questions pertain to the following situation:

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

Formula for parallel connection
1/Rtot = 1/R1 + 1/R2
or
Rtot = R1R2/(R1 + R2)



= 5R/2

Why C instead of R? Unbelievable.

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

a. $C_{eq} = 3R/2$
b. $C_{eq} = 5R$
c. $C_{eq} = 5R/7$
d. $C_{eq} = 4R/3$
e. $C_{eq} = 13R/9$

5R/2 and R are in parallel, so
Rtot = (5R/2)R/(7R/2)
= 5R/7.

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

P = V^2/R

a. P_1 = 1.9 W
b. P_1 = 9.0 W
c. P_1 = 5.7 W

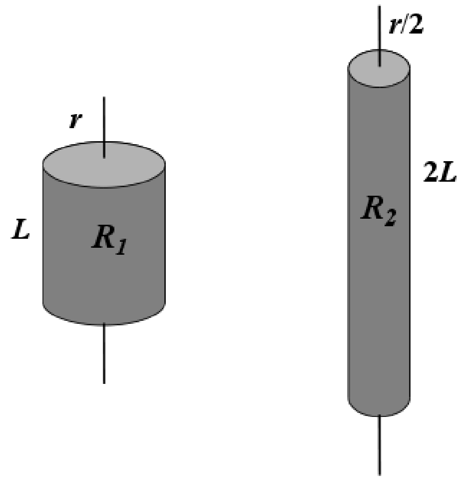
12 V is applied to R1 = R = 75 ohm. Therefore,
P = V^2/R = 12^2/75 = 1.92 W.

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

a. V_{ab} = 2.4 V
b. V_{ab} = 18.2 V
c. V_{ab} = 6.0 V
d. V_{ab} = 12.0 V
e. V_{ab} = 4.8 V

The current I through R2 satisfies I(5R/2) = E or
I = 2E/5R = 24/(5x75) = 0.064 A
The voltage drop due to R2 and R3 must be
(R2 + R3) x 0.064 = 150 x 0.064 = 9.6 V.
Therefore, 12 - 9.6 = 2.4 V is the voltage across R4.

16. Two resistors are created using copper, whose resistivity is ρ = 1.72 x 10^{-8} Ω·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?



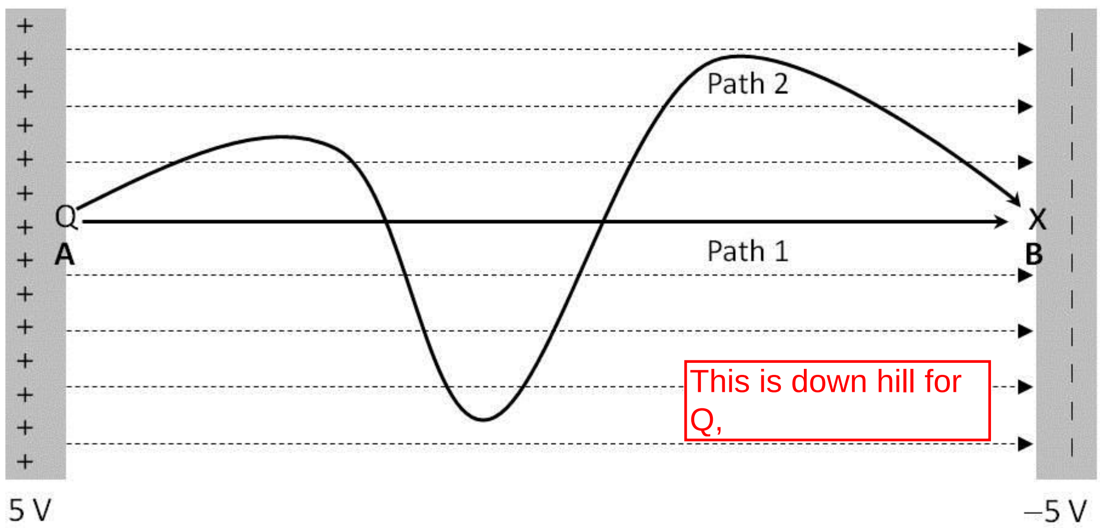
R = ¥rho L/A

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. $R_2/R_1 = 16$

R1 = ¥rho L/(¥pi r^2)
R2 = ¥rho 2L/(¥pi (r/2)^2).
Therefore,
R2/R1 = 2 x 2^2 = 8

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?

a. $W_1 > W_2$
b. $W_1 < W_2$
c. $W_1 = W_2$

The work needed is the potential difference, so it does not depend on the actual paths.

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

a. Not enough information is given.
b. v = 7.75 m/s
c. v = 5.48 m/s
d. v = 173 m/s
e. v = 245 m/s

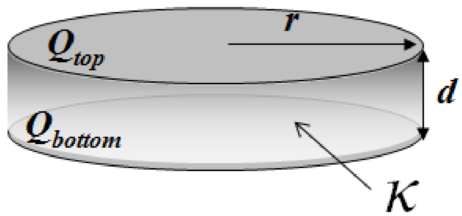
The answer says e ????

The positive charge tumbles down the potential slope from A to B.
The key point is the conservation of energy.

Initial U = 10Q = 30 x 10^{-3} J, initial K = 0
Final U = 0, final K = (1/2) mv^2.
Conservation energy implies
10Q = (1/2) mv^2
Therefore,
v^2 = 20Q/m = 20 x 3 x 10^{-3}/(1 x 10^{-3})
= 60 = (7.746)^2.

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 $\kappa = 2.5$ is placed between the plates. The capacitor is then charged by placing a charge $Q_{top} = +3$ nC on the top plate and $Q_{bottom} = -3$ nC on the bottom plate. After charging, the entire element is disconnected from all other element, such as wires or a battery.



Q/(¥pi r^2) ¥kappa¥epsilon0 is E.

This times d must be E.
Or you can use the capacitance formula:
C = ¥kappa ¥epsilon A/d
and Q = CV.

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

a. $V = 15$ V
b. $V = 54$ V
c. $V = 95$ V
d. $V = 65$ V
e. $V = 225$ V

V = [Q/(pi r^2)¥kappa ¥epsilon0] d
= [(3 x 10^{-9})/(¥pi (2x10^{-3})^2 x 2.5 x 8.85 x 10^{-12})] x (5 x 10^{-6}
= 0.05395 x 10^{-9 + 6 +12 -6} = 0.054 x 10^{3} = 54 V

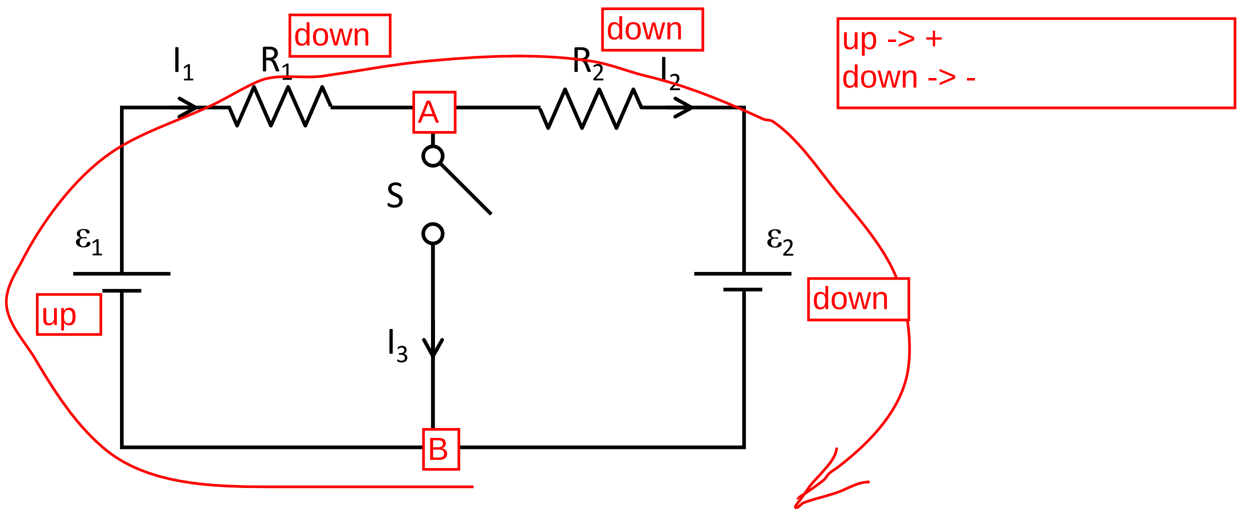
20. The distance between the plates is increased from 5 μm to 20 μm. How does the new charge on the top plate $Q_{top,new}$ compare to the original charge on the top plate Q_{top}?

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

Charge is conserved!

The next three questions pertain to the following situation:

Consider the circuit below. $\mathcal{E}_1 = 15$ V, $\mathcal{E}_2 = 5$ V, $R_1 = 1\ \Omega$, $R_2 = 2\ \Omega$.
Initially the switch *S* is *open*.



21. What is the current I_1 in resistor R_1?

a. $I_1 = 0$ A
b. $I_1 = 6.25$ A
c. $I_1 = 3.33$ A
d. $I_1 = 1.50$ A
e. $I_1 = 17.5$ A

Kirchhoff's voltage law implies (clockwise around the outer loop)

E1 - I1R1 - I2R2 - E2 = 0

I1 = I2

so

I1 = (E1 - E2)/(R1 + R2) = 10/3 = 3.33 A

but this should also be obvious intuitively.

See how to choose the sign above.

22. Now the switch *S* is *closed*. What is the current I_3?

a. $I_3 = 0$ A
b. $I_3 = 6.25$ A
c. $I_3 = 3.33$ A
d. $I_3 = 1.50$ A
e. $I_3 = 17.5$ A

Notice that the voltages at A and .at B are identical (you may assume it is zero). Therefore, Kirchhoff's current law applied at A implies

I1 = I2 + I3

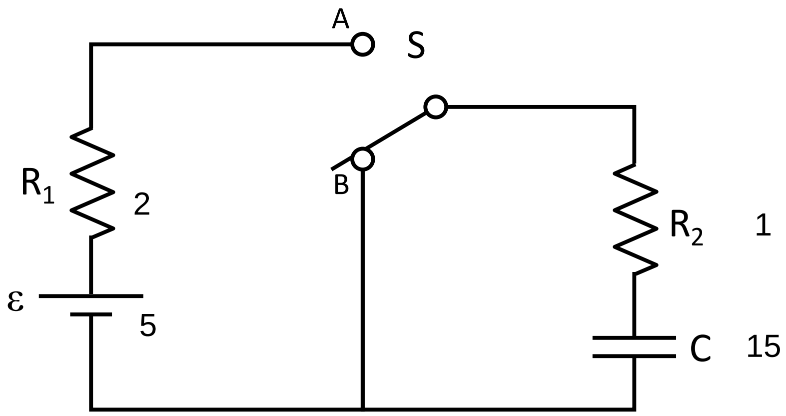
Since VA = 0, I1 = E1/R1 = 15/1 = 15 A

I2 = -E2/R2 = -5/2 = -2.5 A.

Therefore, I3 = I1 - I2 = 17.5 A.

The next five questions pertain to the following situation:

Consider the circuit below. $\mathcal{E}$ = 5 V, R_1 = 2 Ω, R_2 = 1 Ω, and C = 15 μF. Initially the switch S is at position B and the capacitor C is fully discharged.

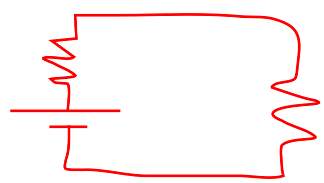


This initial configuration implies that C is not charged at all.

At t = 0, the switch S is flipped to position A.

23. What is the current I_2 in resistor R_2 ***immediately*** after setting the switch to A?

Immediately after switching, the voltage across C is 0, so the effective circuit is



I2 = E/(R1 + R2)
= 5/3 = 1.67 A

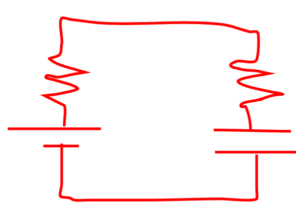
a. I_2 = 0 A
b. I_2 = 1.67 A
c. I_2 = 12.5 A
d. I_2 = 6.33 A
e. I_2 = 5.00 A

24. At some time t > 0 later, the current through R_2 is found to be I_2 = 1.0 A. What is the charge Q on the capacitor C at that precise time?

a. Q = 30 μC
b. Q = 250 μC
c. Q = 75 μC

This implies that the voltage across R2 is I2R2 = 1 V.

Voltage due to R1 and R2 is 3 V



Therefor the voltage across C is 5 - 3 = 2 V.
Q = 2C = 30 x 10^{-6} C.

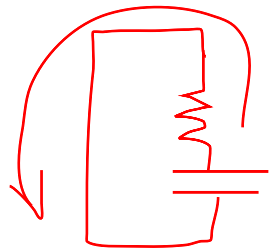
The next three questions continue from the previous page:

After a long time, the switch S is reset to position B. The next three questions pertain to this situation.

25. What is the magnitude of the current I_2 in resistor R_2 ***immediately*** after resetting the switch to B?

After a long time, C is charged up (the voltage across it is 5V, and the current is zero.

a. $I_2 = 0$ A
b. $I_2 = 6.67$ A
c. $I_2 = 5.00$ A
d. $I_2 = 12.5$ A
e. $I_2 = 1.33$ A



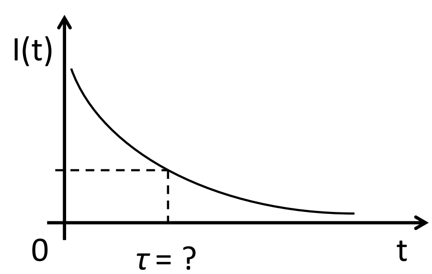
5 V

Thus, immediately after resetting to B, the effective circuit reads as in the left. Hence, I = 5/R2 = 5 A.

26. In what direction around the circuit does the current I flow immediately after resetting the switch?

a. Clockwise
b. Counterclockwise

27. Eventually, the current decays gradually to zero as shown in the figure below. Which formula best represents the time constant τ for this decay?



a. $\tau = R_1C$
b. $\tau = R_2C$
c. $\tau = (R_1+R_2)C$

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