# Unit 3.B - Electric Potential and Capacitance <br> <br> 3.B. 1 Problems - Electric Potential Energy <br> <br> 3.B. 1 Problems - Electric Potential Energy Section 16.1 of your textbook. 

| Early E. C.: 11 |  |
| :---: | :---: |
| Total HW Points |  |
| Unit 3.B: | 128 |
| Total Lab Points |  |
| Unit 3.B: | 140 |
| Unit 3.B Apps. | 15 |
| Late, Incomplete, Units Fee? | Nork, No |

1. A pair of parallel plates is charged by a $12-\mathrm{V}$ battery. If the electric field between the plates is 1200 N/C, how far apart are the plates?

| Possible 3.B. 1 Pts.: | $\mathbf{8}$ |  |
| :--- | :--- | :--- |
| Late, Incomplete, | No work, |  |
| No Units Fee: | -1 | -2 |
| Final Score: | $\mathbf{- 3}$ |  |

If it takes $+1.6 \mathrm{E}-5 \mathrm{~J}$ to move a positively charged particle between two plates:
2. What is the charge on the particle if the plates are connected to a 6.0 V battery?
3. Was it moved from the negative to the positive plate or from the positive to negative?

Consider two points at different distances from a positive test charge.
4. The point closer to the charge is at a (1) higher, (2) equal, (3) lower potential than the point farther away. Why?
5. From the previous problem, how much different is the electric potential 20.0 cm from a charge of $5.5 \mu \mathrm{C}$ compared to 40.0 cm from the same charge?
6. At one-third the original distance from a positive point charge, by what factor is the electric potential changed: (1) $1 / 3$, (2) 3 , (3) $1 / 9$, or (4) 9 ? Why?
7. How far from $\mathrm{a}+1.0 \mu \mathrm{C}$ charge is a point with an electric potential of 10 kV ?
8. How much of a change in potential would occur if the point were moved to three times that distance?

| Possible 3.B. 2 Pts.: |  | 6 |
| :--- | ---: | :--- |
| Late, Incomplete, No work, |  |  |
| No Units Fee: | $-1-2$ | -3 |
| Final Score: | 6 |  |

## 3.B. 2 Problems - Capacitors <br> Section 16.3 of your textbook.

1. How much charge flows through a $12-\mathrm{V}$ battery when a $2.0 \mu \mathrm{~F}$ capacitor is connected across its terminals?
2. What plate separation is required for a parallel plate capacitor to have a capacitance of 9.00 nF if the plate area is $0.425 \mathrm{~m}^{2}$ ?

A 12.0 V battery remains connected to a parallel plate capacitor with a plate area of $0.224 \mathrm{~m}^{2}$ and a plate separation of 5.24 mm . Answer $3-5$ based on this information.
3. What is the charge on the capacitor?
4. How much energy is stored in the capacitor?
5. What is the electric field between its plates?
6. Current state-of-the-art capacitors are capable of storing many times the energy of older ones. Such a capacitor, with a capacitance of 1.0 F , is able to light a 0.50 W bulb at steady full power for 5.0 s before it quits. What is the terminal voltage of the battery that charged the capacitor?

## 3.B. 3 Problems - Dielectrics <br> Section 16.4 of your textbook.

Possible 3.B. 3 Pts.: 6
Late, Incomplete, No work, No Units Fee: $\quad-1-2-3$
Final Score: I 6

1. A capacitor has a capacitance of 50.0 pF , which increases to 150.0 pF when a dielectric material is between its plates. What is the dielectric constant of the material?

Answer the following 2 questions based on this information. A 50.0 pF capacitor is immersed in silicone oil, which has a dielectric constant of 2.6. When the capacitor is connected to a 24 V battery,
2. What will be the charge on the capacitor?
3. How much energy is stored in the capacitor?

A parallel plate capacitor has a capacitance of $1.5 \mu \mathrm{~F}$ with air between the plates. The capacitor is connected to a 12 V battery and charged. The battery is then removed. When a dielectric is placed between the plates, a potential difference of 5.0 V is measured across the plates.
4. What is the dielectric constant of the material?
5. What happened to the energy storage of the capacitor: (1) it increased, (2) it decreased, or (3) it remained the same? Explain your choice.
6. By how much did the energy storage of this capacitor change when the dielectric was inserted?

| Possible 3.B.4 Pts.: | $\mathbf{8}$ |  |
| :--- | ---: | ---: |
| Late, Incomplete, No work, |  |  |
| No Units Fee: | $-1-2$ | -3 |
| Final Score: | $\mathbf{8}$ |  |

## 3.B.4 Problems - Capacitor Circuits Section 16.5 of your textbook.

What is the equivalent capacitance of two capacitors with capacitances of $0.40 \mu \mathrm{~F}$ and $0.60 \mu \mathrm{~F}$ when they are connected:

1. In series.
2. In parallel.
3. Two identical capacitors are connected in series and their equivalent capacitance is $1.0 \mu \mathrm{~F}$. What is each one's capacitance value? Repeat the calculation if they were in parallel.
4. Two capacitors can be connected to a battery in either a series or parallel combination. The parallel combination will draw (1) more, (2) equal, (3) less energy from a battery than the series combination? Explain.
5. Two uncharged capacitors, one $0.75 \mu \mathrm{~F}$ and $0.30 \mu \mathrm{~F}$, are connected in series to a $12-\mathrm{V}$ battery. Then the capacitors are disconnected, discharged, and reconnected to the same battery in parallel. Calculate the energy storage of the capacitor circuit in both cases.
6. Three capacitors of equal capacitance are connected in parallel to a battery, and together they acquire a certain total charge Q from that battery. Will the charge on each capacitor be (1) Q , (2) 3 Q , or (3) $\mathrm{Q} / 3$ ?
7. Three capacitors of $0.25 \mu \mathrm{~F}$ each are connected in parallel to a $12-\mathrm{V}$ battery. What is the charge on each capacitor?
8. How much total charge was acquired from the battery in the previous problem?

| AP Physics 2 | Unit 3.B.1 Lab - Capacitors |  |
| :---: | :---: | :---: |
| Reminder: Update Table of Contents |  | Correction Credit: <br> Half |

## Lab Overview:

Students investigate the energy storage parameters of different capacitors in circuit.

## Materials:

Variety of polarized capacitors
Green LEDs
Jumper wires
Fancy Power Supply
Multimeter
100 Ohm resistor
Switch
Breadboard Circuit Design Center


| Capacitor Lab (3.B.1) Guide |  |  |
| :---: | :---: | :---: |
| Table of Contents, Title/Date, Detailed <br> Synopsis, Two Purposes | $/ 2$ |  |
| Mission 1: | Observations | $/ 4$ |
| Mission 2: | Observations | $/ 4$ |
| Analysis 1: Energy Storage 1. |  | $/ 2$ |
| Analysis 1: Energy Storage 2. |  | $/ 2$ |
| Question 1: LED Comparison. |  | $/ 2$ |
| Question 2: Difficulties Encountered. | $/ 2$ |  |
| Work Not Shown Fee: |  | $-1-2-3$ |
| Late Lab Fee: |  | -4 |
| Total: |  | $\mathbf{1 8}$ |

## Mission 1: Capacitor Circuit 1

Make the circuit shown here, but don't apply power until you read through the entirety of the mission. I will help you interpret symbols, and you can look at the one set up in the back of the room for example. Be sure to abide by polarity - the white or red wires correspond to positive voltage, and black or blue wires correspond to negative.

Turn the power adjustment knob of the Power Supply all
 the way counterclockwise. Be sure the 0-24 DC V blue button is in. With your switch open, turn on the power supply. Adjust the kno b until the red display reads 3.0 V . This might fluctuate a little as you operate, just move it as needed. Close the switch, and note what happens to the LED. Open the switch and note what happens to the LED. Next, disconnect the capacitor and note what happens when you close the switch. Now, with the capacitor still disconnected, open the switch and note what happens.

Now set the voltage to 6.0 V . and repeat the previous steps. Note if there is a difference in LED intensity, duration after switching the power, etc.

## Mission 2: Capacitor Circuit 2

Repeat Mission 1, but with a different capacitor. At some point in the lab, try using one of the larger capacitors (greater than $1000 \mu \mathrm{~F}$ ).

## Analysis: 2 Points Each - Show all your work.

1. Calculate the energy stored in your capacitor at both voltages in Mission 1.
2. Calculate the energy stored in your capacitor at both voltages in Mission 2.

## Questions: 2 Points Each

1. How did the LED operation compare at the two different voltages for both of your capacitors?
2. What were some issues you encountered in this lab that could be addressed in the future?

## AP Physics 2

## Reminder: Update Table of Contents

## Lab Overview:

Students investigate different capacity of parallel and serial capacitor circuits. Note: you will be using polarity dependent capacitors, whose symbol is below. Use this symbol in diagrams, and be sure to check polarity when hooking up the battery.

## Materials:

Variety of Polarized Capacitors Jumper Wires; Battery Wires


Capacitometer - one for the whole class!
Regular Multimeter
Breadboard Circuit Design Center

## Mission 1: Parallel Capacitor Circuit

In a data table, write down the printed values of three capacitors. Next, measure the values of these three capacitors with the meter and record them in the table. The reason for this is that the meter vs. factory values are usually different.

Make a parallel capacitor circuit with the three capacitors, then measure the capacitance of the circuit

| Capacitor Circuits Lab (3.B.2) Guide |  |
| :---: | :---: |
| Table of Contents, Title/Date, Detailed Synopsis, Two Purposes | / 2 |
| Mission 1: 3 3 Capacitors (Printed) | / 1 |
| Parallel 3 Capacitors (Measured) | / 1 |
| Capacitors <br> (Data Table) Measured Circuit <br> Capacitance (Parallel) | / 2 |
| Mission 2: Measured Circuit <br> Capacitance (Serial) <br> Seial  | / 2 |
| Serial Battery Voltage | / 1 |
| Capacitors 3 Capacitors' Voltage | / 1 |
| Circuit Diagram | / 2 |
| Analysis 1: Parallel capacitance | 12 |
| Analysis 2: Serial capacitance | / 2 |
| Analysis 3: Serial stored energy | 12 |
| Question 1: Voltage comparison | / 2 |
| Question 2: Difficulties Encountered. | 12 |
| Work Not Shown Fee: | -1-2-3 |
| Late Lab Fee: | -5 |
| Total: | / 22 | with the meter, and put it in the table.

## Mission 2: Serial Capacitor Circuit

Using the same three capacitors, make a series circuit. Next, measure the capacitance and record it in the same table as in Mission 1.

NOTE!! Do not measure capacitance after the following step! You could fry the meter.
Hook up a battery to the circuit. Measure and record the total DC voltage that the battery generates, then measure and record the voltages across the three capacitors.

Draw a circuit diagram of you battery serially joined with your three resistors. Include battery voltage, and the measured capacitance of each capacitor in your diagram.

## Analysis: Show all your work for full credit.

1. Calculate the total capacitance of Mission 1. Compare this to your measured value.
2. Calculate the total capacitance of Mission 2. Compare this to your measured value.
3. Calculate the energy stored in the charged circuit of Mission 2.

## Questions: Answer completely for full credit.

1. From Mission 2, how did the measured voltage compare from capacitor to capacitor? Was there a correlation between voltage and capacitance? Did the total add up to the voltage of the battery?
2. What were some issues or misunderstandings you encountered in this lab that could be addressed in the future?

| AP Physics 2 | Unit 3.B - Electric Potential \& Capacitance |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Application Problems, AP Test Preparation Questions |  |  |  |  |  |
| Presentation <br> Points: | $I 5$ | Late Fee: | -2 | Completion <br> (Booklet Check) | $/ 5$ |

Your grade on this problem set depends on the presentation you provide for your assigned problems, and whether all problems are complete when you submit your Booklet at the end of the Unit.

1. Rank the magnitude of the electric field strength between the plates of the following parallel plate capacitors from greatest to least.

2. What is the equivalent capacitance of the capacitor network shown?

## Unit 3.B Practice AP Multiple Choice Questions

The following problems (multiple choice and free response) are designed to train you to take the AP Physics 1 test in the spring, and will be scored at the end of the Unit - based on completion and accuracy.

1. A parallel-plate air-gap capacitor of capacitance $C$ is attached to a constant voltage supply, storing an amount of energy U . The capacitor is then modified in such a way that the area of the plates is halved, the separation between the plates is doubled, and the air-gap is filled with a dielectric of relative permittivity $\mathrm{k}=4$. What is the amount of energy stored in this new capacitor?
a. $\mathrm{U} / 4$
b. $\mathrm{U} / 2$
c. U
d. 2 U
e. 4 U
2. An air-gap parallel plate capacitor is charged and then disconnected. While it is disconnected, a dielectric is inserted between the plates. What happens to the stored electric potential energy in the capacitor?
a. It increases.
b. It decreases.
c. It stays the same.
3. A battery is connected to an air-gap parallel-plate capacitor. While the battery is connected, a dielectric is inserted between the plates of the capacitor. Which of the following statements are true? Choose two answers.
a. The capacitance of the system increases.
b. The energy stored in the capacitor decreases.
c. The potential difference across the capacitor increases.
d. The charge on the plates increases.
e. The electric field between the plates increases.
4. An insulated metal sphere, $A$, is charged to a value of $+Q$ elementary charges. It is then touched and separated from an identical but neutral insulated metal sphere, B. This second sphere is then touched to a third identical and neutral insulated metal sphere C. Finally, spheres A and C are touched and then separated. Which of the following represents the distribution of charge on each sphere, respectively, after the above process has been completed?
a. $\mathrm{Q} / 3, \mathrm{Q} / 3, \mathrm{Q} / 3$
b. $\mathrm{Q} / 4, \mathrm{Q} / 2, \mathrm{Q} / 4$
c. $3 \mathrm{Q} / 8, \mathrm{Q} / 4,3 \mathrm{Q} / 8$
d. $3 \mathrm{Q} / 8, \mathrm{Q} / 2, \mathrm{Q} / 4$
5. What is the capacitance of a parallel-plate capacitor made by two square aluminum plates, 4 cm in length and separated by 5 mm ?
a. $2.832 \mathrm{E}-11 \mathrm{~F}$
b. 2.832 E-10 F
c. $2.832 \mathrm{E}-12 \mathrm{~F}$
d. 2.832 E -9 F
6. Which points in this uniform electric field (between the plates of the capacitor) shown above lie on the same equipotential?
(A) 1 and 2 only
(B) 1and 3 only
(C) 2 and 4 only
(D) 3 and 4 only
(E) 1,2,3 and 4 all lie on the same equipotential since the electric field is uniform

7. If each of the capacitors in the array shown is $C$, what is the capacitance of the entire combination?
(A) $\mathrm{C} / 2$
(B) $2 \mathrm{C} / 3$
(C) $5 \mathrm{C} / 6$
(D) 2 C
(E) $5 \mathrm{C} / 3$


## Unit 3.B Example AP Question - Free Response

A 1-g cork sphere on a string is coated with silver paint. It is in equilibrium, making a $10^{\circ}$ angle in a uniform electric field of 100 N/C as shown in the diagram. What is the charge on the sphere?


| AP Physics 2 |  | Unit 3.B Review - Electric Potential \& Capacitance |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Points: | I 20 | Late or <br> Incomplete Fee: | $-2-4-6$ | Correction <br> Credit: | Final <br> Score: |  |

Solve these problems here, THEN enter your responses in the bubble sheet provided.

Each question is worth two points.
Metric Prefix Review
Complete the following table.

| Prefix | Symbol | Multiplier |
| :---: | :---: | :---: |
| Tera | T | E 12 |
|  | G |  |
| Mega |  |  |
|  | h | E 3 |
|  |  |  |
| Deka | c |  |
| Deci | $\mu$ | $\mathrm{E} \mathrm{-3}$ |
|  | p |  |
|  |  |  |
| Nano |  |  |
|  |  |  |




1. Convert 4.96 E 14 pg to kg.
A) 496 kg
B) $4.96 \mathrm{E}-3 \mathrm{~kg}$
C) 4.96 kg
D) 49.6 kg
E) 0.496 kg
2. Convert $6.33 \mathrm{E}-11 \mathrm{~cm}$ to nm .
A) $6.33 \mathrm{E}-4 \mathrm{~nm}$
B) 633 nm
C) 6.33 E 3 nm
D) $6.33 \mathrm{E}-1 \mathrm{~nm}$
E) 63.3 nm
3. Convert 12 TC to MC.
A) $12,000 \mathrm{MC}$
B) 12 E 6 MC
C) 12 MC
D) $1.2 \mathrm{E}-2 \mathrm{MC}$
E) 120 MC
4. Convert $2.4 \mathrm{E} 4 \mu \mathrm{~V}$ to mV .
A) 24 mV
B) 0.24 mV
C) 2.4 E 3 mV
D) 240 mV
E) 2.4 mV
5. If it takes $+3.2 \mathrm{E}-4 \mathrm{~J}$ to move a positively charged particle between two charged parallel plates, what is the charge on the particle if the plates are connected to a 12 volt battery?
A) $2.67 \mathrm{E}-3 \mathrm{C}$
B) $2.67 \mathrm{E}-1 \mathrm{C}$
C) $2.67 \mathrm{E}-5 \mathrm{C}$
D) 2.67 E 3 C
E) 2.67 E 5 C
6. A parallel plate capacitor has a plate area of $0.525 \mathrm{~m}^{2}$ and a plate separation of 2.15 mm . What is its capacitance?
A) $2.19 \mathrm{E}-6 \mathrm{~F}$
B) $2.19 \mathrm{E}-3 \mathrm{~F}$
C) $2.19 \mathrm{E}-12 \mathrm{~F}$
D) $2.19 \mathrm{E}-8 \mathrm{~F}$
E) $2.19 \mathrm{E}-9 \mathrm{~F}$
7. What is the capacitance of a device that can store $3.5 \mathrm{E}-8 \mathrm{C}$ of charge with a resulting voltage of 24 V ?
A) $1.86 \mathrm{E}-9 \mathrm{~F}$
B) $2.93 \mathrm{E}-9 \mathrm{~F}$
C) $1.25 \mathrm{E}-9 \mathrm{~F}$
D) $1.46 \mathrm{E}-9 \mathrm{~F}$
E) $2.12 \mathrm{E}-9 \mathrm{~F}$
8. A capacitor has a capacitance of 42 nF , which increases to 68 nF when a dielectric material is placed between its plates. What is the dielectric constant of the material?
A) 1.62
B) 0.46
C) 9.50
D) 2.40
E) 7.80
9. What is the capacitance of this circuit?
A) $9.0 \mu \mathrm{~F}$
B) $3.3 \mu \mathrm{~F}$
C) $15 \mu \mathrm{~F}$
D) $8.0 \mu \mathrm{~F}$
E) $12 \mu \mathrm{~F}$
10. What is the maximum charge storage of this circuit?
A) $1.24 \mathrm{E}-4 \mathrm{C}$
B) $3.09 \mathrm{E}-4 \mathrm{C}$
C) $4.20 \mathrm{E}-4 \mathrm{C}$
D) $2.97 \mathrm{E}-4 \mathrm{C}$
E) $2.10 \mathrm{E}-4 \mathrm{C}$
