Name: ____________________________________________
Student ID: ____________________________
Section #: _______
1) [20 points, 4 points each]. Circle the correct answer, AND write some sentences or show a calculation explaining how you obtained the answer.

i) A parallel-plate capacitor is connected to a battery and charged. The battery is then disconnected, and the plates are stretched, so that they have twice the area that they had originally. How does the stored energy $U_{after}$ compare to stored energy $U_{before}$ stretching the plates?

- a. $U_{after}=2U_{before}$
- b. $U_{after}=U_{before}/2$
- c. $U_{after}=4U_{before}$
- d. $U_{after}=U_{before}/4$
- e. $U_{after}=U_{before}$

**Explanation/Work:**

ii) A charge $q_1=-2 \mu C$ is fixed in space as shown. What is the minimum work you must do to move a second charge $q_2=+10 \mu C$ charge from point A=(0,1) m to point B=(2, 0) m?

- a) 0.2J
- b) -0.18J
- c) -0.09J
- d) 0.09J
- e) 0.18J

**Explanation/work:**

iii) An electron is in a uniform electric field of $2\times10^{-6}$ V/m. There are no other forces apart from the electric field. Calculate the acceleration of the electron.

**Explanation/work:**

<table>
<thead>
<tr>
<th>accel</th>
<th>Value</th>
<th>Units</th>
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<tbody>
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iv) In the resistor-capacitor circuit below, the switch was opened after charging the \(10\mu F\) capacitor with a charge of \(Q_0=20\ \mu C\). The switch is then closed again. What is the current through the \(1\ k\Omega\) resistor immediately after the switch is closed? (\(1\ k\Omega=1000\Omega\) and \(1\mu F=10^{-6}\ F\))

- a. 0 A
- b. 0.002 A
- c. 0.005 A
- d. 0.008 A
- e. 0.01 A
- f. 0.1 A
- g. 0.8 A

**Explanation/Work**

\[
Q_0 = 20\ \mu C
\]

v) Calculate the current through the resistor \(R_2\). The battery voltage is 10V.

- a) 0.1A
- b) 0.2A
- c) 0.25A
- d) 0.3A
- e) 0.4A.
- f) 0.5A
- g) 1.0A

**Explanation/work:**
2) [20 points total] This problem concerns two conducting plates, each of size 0.4m X 0.5m, separated by \(d=1\text{mm}\). The left plate has charge \(-Q=-0.1\mu\text{C}\) and the right plate has charge \(+Q=+0.2\mu\text{C}\). Assume that the electric fields arising from the plates are the same as from plates of infinite extent with the same charge density, and that the plates have negligible thickness.

Graph the potential \(V\) and \(x\)-component of the electric field \(E_x\) as a function of distance along the \(x\)-axis. Plot both between and outside the plates.

For the electric field, use a positive value to indicate that the field points to the right.

For the potential, take the left plate as zero potential.

For full credit, you need both for the correct sign and the correct \(x\)-dependence.

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**a) [5 points] E-field plot**

(E>0 means field points to right)

**b) [5 points] Potential plot**

(left plate has \(V=0\))
c) **[10 pts]** Calculate the electric potential difference between the right plate and the left plate $V_{\text{right plate}} - V_{\text{left plate}}$. Make sure you get the sign correct.

\[ V_{\text{right plate}} - V_{\text{left plate}} = \]
3) [20 points total]
An infinite solid conducting plate of thickness 0.5cm is placed in a uniform electric field of 10 N/C as shown below. The plate is uncharged.

a) [5 points] What is the electric field in the middle of the plate (marked x in the figure)? EXPLAIN.

\[ E_{\text{middle}} = \]

b) [5 points] Calculate the charge densities on the left and right surfaces of the plate. Make sure you get the signs right!

\[ \eta_{\text{left}} = \]
\[ \eta_{\text{right}} = \]

c) [10 points] Calculate the electric potential difference \( V_B - V_A \) shown in the figure.

\[ V_B - V_A = \]
4) **[20 points total]** Short problems dealing with current and circuits.

a) **[5 points]** A light bulb has a resistance of 100Ω. If electricity costs 20 cents per kW-hour (1kW=1000W), how much does it cost to run the light bulb for one day when powered with 120V?

\[
\text{Cost} = \begin{array}{c|c}
\text{Value} & \text{Units} \\
\hline
 & \\
\end{array}
\]

b) **[5 points]** A scientist tests the resistivity of sea water by filling a cylinder 0.5cm diameter and 5cm long. When applying a potential difference of 10V across the ends of the cylinder, she measures a current of 40mA. What is the resistivity of the seawater?

\[
\text{Resistivity} = \begin{array}{c|c}
\text{Value} & \text{Units} \\
\hline
 & \\
\end{array}
\]

c) **[5 points]** The voltage supplying an RC circuit is continually adjusted so that the current through the resistor is always 5µA (1µA=10⁻⁶A). If the capacitor has no charge at time \( t=0 \), what is the voltage drop across the capacitor after 10 seconds?

\[
\text{Voltage} = \begin{array}{c|c}
\text{Value} & \text{Units} \\
\hline
 & \\
\end{array}
\]
d) **[5 points]** In the following resistor-capacitor circuit, calculate the charge \( Q_2 \) on capacitor \( C_2 \) a long time after the switch is closed.

\[
\begin{array}{|c|c|}
\hline
\text{Value} & \text{Units} \\
\hline
\text{Q}_2 & \\
\hline
\end{array}
\]
5) [20 pts] Short question regarding magnetic fields and forces. In all the parts, an infinitely long wire carries a current of 10A

a) [5 pts] Calculate the magnitude and direction of the magnetic field +2 cm from the wire on the x-axis (location marked with x).

\[
B = \begin{array}{c|c|c}
\text{Value} & \text{Units} & \text{Direction} \\
\hline
\end{array}
\]

b) [5 pts] A particle of charge \( q = -1 \text{ mC} \) \((1 \text{ mC} = 10^{-3} \text{ C})\) moves along the z-axis at a speed of 100 m/s as shown in the figure. It is +4 cm from the wire. Calculate the magnitude and direction of the force on the charged particle.

\[
\text{Force} = \begin{array}{c|c|c}
\text{Value} & \text{Units} & \text{Direction} \\
\hline
\end{array}
\]
c) [5 pts] A 2 cm X 2 cm square loop of wire in the xy plane has a current circulating around it of 2 A. The edge of the loop is 2 cm from the wire in the +x direction. Calculate the direction of the net force on the loop.

Direction = 

\[ \text{Dipole moment} = \]

\begin{tabular}{|c|c|c|}
\hline
\text{Value} & \text{Units} & \text{Direction} \\
\hline
\end{tabular}

d) [5 pts] Calculate the magnetic dipole moment of the 2 cm X 2 cm square loop. It still carries 2A of current.