Physics 126: Practice Midterm #1

This practice midterm was the first midterm exam given during Winter 2006. The median score on this exam was 14/20.

This is a closed-book exam lasting 90 minutes. You may use a calculator and a 3” x 5” “crib sheet.” The exam contains 20 multiple-choice questions.

Before you begin:
1. Fill in your name and section number on your Scantron sheet. Fill in your 8-digit UM ID (not your SSN) in the space indicated.
2. Fill in the version number of your exam in the area of the Scantron marked “Form.” Your exam version number is 1.
3. Sign and date your Scantron.

Useful Physical Constants:

<table>
<thead>
<tr>
<th>Physical Constant</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>proton charge</td>
<td>$e = 1.602 \times 10^{-19} \text{ C}$</td>
</tr>
<tr>
<td>electron mass</td>
<td>$m_e = 9.1 \times 10^{-31} \text{ kg}$</td>
</tr>
<tr>
<td>proton mass</td>
<td>$m_p = 1.7 \times 10^{-27} \text{ kg}$</td>
</tr>
<tr>
<td>permittivity of free space</td>
<td>$\varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{N} \cdot \text{m}^2)$</td>
</tr>
<tr>
<td>coulomb's law constant</td>
<td>$k = 1/(4\pi\varepsilon_0) = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$</td>
</tr>
<tr>
<td>permeability of free space</td>
<td>$\mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m}/\text{A}$</td>
</tr>
<tr>
<td>speed of light in vacuum</td>
<td>$c = 3.00 \times 10^8 \text{ m/s}$</td>
</tr>
<tr>
<td>acceleration of gravity</td>
<td>$g = 9.8 \text{ m/s}^2$</td>
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</table>
1. Two metal spheres A and B are touching. A negatively charged wand is brought close to the sphere A, as shown. The two spheres are separated slightly and the wand is taken away. At the end of this procedure:

   A) Sphere A is positive and B negative.
   B) Sphere A is negative and B positive.
   C) Both A and B are negative
   D) Both A and B are positive
   E) Both spheres are neutral.

   Electrons are repelled to the right leaving net positive charge on Sphere A and net negative charge on Sphere B.

2. The diagrams show five different charge situations. The charges are all the same distance from the origin. Rank the situations according to the magnitude of the electric field at the origin, from greatest to least.

   A) 1, 2, 3, 4
   B) 4, 3, 2, 1
   C) 2, 1, then 3 and 4 tie
   D) 1, 2, then 3 and 4 tie
   E) 4, 3, 1, 2
3. Positive charge +Q is distributed uniformly on the upper half of a rod and negative charge –Q is distributed uniformly on the lower half. What is the direction of the electric field at the point P on the perpendicular bisector of the rod?

A) ↑
B) ↓
C) ←
D) →
E) ↗

4. A charged oil drop with mass \(2 \times 10^{-4}\) kg is held suspended in the Earth’s gravitational field by a downward electric field of 300 N/C. The charge on the drop is:

A) \(+1.5 \times 10^{-6}\) C
B) \(-1.5 \times 10^{-6}\) C
C) \(+6.5 \times 10^{-6}\) C
D) \(-6.5 \times 10^{-6}\) C
E) 0 C

\[qE = mg\]
\[q = \frac{mg}{E} = \frac{(2 \times 10^{-4})(9.8)}{300} = -6.5 \times 10^{-6}\) C

5. A configuration of charges is shown below. At which point along the x-axis does the force on a positive test charge equal zero?

Force on a positive charge can cancel only for \(x > 5\) cm.

\[
\frac{k(2q)}{(x+5)^2} = \frac{kq}{(x-5)^2}
\]

\[
\sqrt{2}(x-5) = (x+5)
\]

\[
(\sqrt{2} - 1)x = (\sqrt{2} - 1)5
\]

\[
x = 29.1\]
6. Surface 1 and 2 are perpendicular to one another. The electric field, indicated by the arrows, is uniform with a magnitude of 120 N/C. The area of surface 2 is 0.75 m². What is the magnitude of the flux through surface 2?

\[ \Phi = EA \cos \theta = (120)(0.75) \cos(65) = 38.0 \text{ Nm}^2/\text{C} \]

A) 38 N m²/C
B) 81.6 N m²/C
C) 90 N m²/C
D) 120 N m²/C
E) Cannot be determined without knowing the enclosed charge.

7. A spherical conducting shell has a net charge of -25 \( \mu \text{C} \). A 5 \( \mu \text{C} \) charge is placed in the center of the cavity. The charge on the inner (outer) surfaces of the shell is:

A) -5 \( \mu \text{C} \) (0 \( \mu \text{C} \))
B) 0 \( \mu \text{C} \) (-25 \( \mu \text{C} \))
C) -5 \( \mu \text{C} \) (5 \( \mu \text{C} \))
D) 5 \( \mu \text{C} \) (-30 \( \mu \text{C} \))
E) -5 \( \mu \text{C} \) (-20 \( \mu \text{C} \))

Hint: Use Gauss’ Law

8. A battery is used to charge a parallel-plate capacitor, after which it is disconnected. Then the plates are pulled apart to twice their original separation. This process will double the:

A) capacitance
B) surface charge density on each plate
C) stored energy
D) electric field between the plates
E) charge

\[ C = \varepsilon_0 A/d \]
\[ C \rightarrow C/2, \quad Q \text{ stays same} \]
\[ V = Q/C \rightarrow 2V \]
E stays same

Volume doubles \( \rightarrow \) stored energy doubles
9. A 2-\(\mu\)F and a 1-\(\mu\)F capacitor are connected in series and a potential difference is applied across the combination. The 2-\(\mu\)F capacitor has:

A) twice the charge of the 1-\(\mu\)F capacitor  
B) half the charge of the 1-\(\mu\)F capacitor  
C) twice the potential difference of the 1-\(\mu\)F capacitor  
D) half the potential difference of the 1-\(\mu\)F capacitor  
E) none of the above

10. A 2-\(\mu\)F and a 1-\(\mu\)F capacitor are connected in parallel and a potential difference is applied across the combination. The 2-\(\mu\)F capacitor has:

A) twice the charge of the 1-\(\mu\)F capacitor  
B) half the charge of the 1-\(\mu\)F capacitor  
C) twice the potential difference of the 1-\(\mu\)F capacitor  
D) half the potential difference of the 1-\(\mu\)F capacitor  
E) none of the above

11. Three point charges (+2q, -q and -q with \(q = 2.0 \times 10^{-5} \text{ C}\)) are located on a line as shown in the figure. If a third charge \(-2q\) is brought from infinity and placed on the line at position A, what will its electric potential energy be? Pick the closest value.

\[
\begin{align*}
\text{EPE} &= k(-2q) \left[ \frac{2q}{d} + \frac{-q}{d} + \frac{-q}{3d} \right] = \frac{-4kq^2}{3d} \\
&= -4(8.99 \times 10^9)(2 \times 10^{-5})^2 / (3 \times 0.25) = -19.2 J
\end{align*}
\]
12. A proton moves in a constant electric field $E$ from point A to point B. The magnitude of the electric field is $4.2 \times 10^4$ N/C; and it is directed as shown in the drawing, the direction opposite to that of the proton. If the distance from point A to point B is 0.18 m, what is the change in the proton’s electric potential energy, $E_{PE_B} - E_{PE_A}$?

$E_{PE_B} - E_{PE_A} = qEd = (1.6 \times 10^{-19})(4.2 \times 10^4)(0.18)$

$= 1.2 \times 10^{-15}$ J

A) $+2.4 \times 10^{-15}$ J  
B) $-1.2 \times 10^{-15}$ J  
C) $+1.2 \times 10^{-15}$ J  
D) $-2.4 \times 10^{-15}$ J  
E) $-1.8 \times 10^{-15}$ J

13. In the circuit below, find the current through resistor $R_1$.

$R_{eq} = 16 + (12 \times 24)/(12 + 24) = 16 + 8 = 24 \Omega$

$I_1 = 12/24 = 0.5$ A
14. The plates of a parallel plate capacitor each have an area of 0.40 m$^2$ and are separated by a distance of 0.02 m. They are charged until the potential difference between the plates is 3000 V. The charged capacitor is then isolated. If a dielectric sheet is inserted to completely fill the space between the plates, the potential difference between the plates drops to 1000 V. Determine the dielectric constant.

A) 0.333  
B) 0.666  
C) 3.0  
D) 6.0  
E) 2000

\[ C = \kappa \varepsilon_0 \frac{A}{d} \]

Q remains the same

\[ \frac{V}{C} \rightarrow \kappa C \]

V decreases by 3 so

C must increase by 3. \( \kappa = 3 \)

15. A dielectric slab is slowly inserted between the plates of a parallel plate capacitor, while the potential difference between the plates is held constant by a battery. As it is being inserted:

A) the capacitance, the potential difference between the plates, and the charge on the positive plate all increase  
B) the capacitance, the potential difference between the plates, the charge on the positive plate all decrease  
C) the potential difference between the plates increases, the charge on the positive plate decreases, and the capacitance remains the same  
D) the capacitance and the charge on the positive plate decrease but the potential difference between the plates remains the same  
E) the capacitance and the charge on the plate increase but the potential difference between the plates remains the same

\[ C = \kappa \varepsilon_0 \frac{A}{d} \]

V remains the same

\[ \frac{C}{V} \rightarrow \kappa C \text{ (increases)} \]

Q = CV (increases)
16. Two charges of opposite sign and equal magnitude \( Q = 2.0 \, \text{C} \) are held 2.0 m apart as shown in the figure.

\[ V = \frac{kQ}{r} - \frac{kQ}{4r} = 0 \]
\[ W = qV = 0 \]

How much work is required to move a 1.0 C charge from infinity to the point \( P \)?

- A) zero joules
- B) \( 2.2 \times 10^9 \) J
- C) \( 4.5 \times 10^9 \) J
- D) \( 9.0 \times 10^9 \) J
- E) infinity

17. The “Ampere hour” is a unit commonly used to express the amount of charge that can be stored in an automobile battery. Suppose you have a fully-charged 12 Volt battery with an 84 amp hour rating. At time \( t = 0 \) you connect a light bulb with 2 ohm resistance to the battery terminals. Estimate the length of time that the current would flow in that light bulb.

- A) 14 hours
- B) 42 hours
- C) 6 hours
- D) 2 hours
- E) 84 hours

18. A battery is used to illuminate a distant light bulb that has a resistance of 300 ohms. The connection between the battery and the light bulb is made with a long wire that is 30 meters long and 1 mm diameter. That wire has a resistance of 0.6 ohms. Because of this resistance, power is wasted. If you wanted to reduce that wasted power by a factor of 4 by changing the diameter of the wire, what would be the new diameter of the wire?

- A) 2 mm
- B) 0.7 mm
- C) 1.414 mm
- D) 4 mm
- E) 6.14 mm

\[ V = kQ/4 - kQ/4 = 0 \]
\[ W = qV = 0 \]

\[ I = V/R = 12/2 = 6 \, \text{A} \]
\[ 84 \, \text{Amp-hr}/6A = 14 \, \text{hrs} \]

\[ 300 >> 0.6 \, \text{so I will be ~ the same before and after} \]
\[ P_{\text{wasted}} = I^2R_{\text{wire}} \]

To reduce wasted power by 4 you want \( R_{\text{wire}} \) reduced by 4 which requires increasing the radius (diameter) by 2 to 2mm.
19. The efficiency of an electrical power transmission system is defined by the ratio:

\[ \frac{\text{power delivered to load}}{\text{power delivered by battery}} = \frac{I^2R_2}{IV} = \frac{V}{(R_1 + R_2)} \left( \frac{R_2}{V} \right) = \frac{R_2}{R_1 + R_2} \]

Of the following five circuits, which is the most efficient in delivering power to the load?

(A) 120 Volts

\[ R_1 = 11 \text{ Ohms} \]

\[ R_2 = 1 \text{ Ohm} \]

(B) 120 Volts

\[ R_1 = 9 \text{ Ohms} \]

\[ R_2 = 3 \text{ Ohms} \]

(C) 120 Volts

\[ R_1 = 6 \text{ Ohms} \]

\[ R_2 = 6 \text{ Ohms} \]

(D) 120 Volts

\[ R_1 = 3 \text{ Ohms} \]

\[ R_2 = 9 \text{ Ohms} \]

(E) 120 Volts

\[ R_1 = 1 \text{ Ohm} \]

\[ R_2 = 11 \text{ Ohms} \]

Efficiency

\[ \frac{1}{12} \]

\[ \frac{3}{12} \]

\[ \frac{6}{12} \]

\[ \frac{9}{12} \]

\[ \frac{11}{12} \]
20. In the circuit below bulbs #1 and #2 are illuminated in all cases. Describe what happens when one closes Switch #3. Choose the correct alternative:

A) The current drawn from the battery is 1 ampere until switch #3 closes and bulb #3 illuminates. The battery current then increases to 1.33 amperes; As bulb #3 turns on, bulb #2 becomes dimmer and bulb #1 becomes brighter.

B) The current drawn from the battery is 1 ampere until switch #3 closes; the current then rises to 1.33 amperes as bulb #3 illuminates. Bulbs #1, #2 and #3 are now equally bright.

C) The current drawn from the battery is 2 amperes until switch #3 closes and bulb #3 illuminates. The battery current then increases to 3 amperes; bulb #2 becomes brighter and bulb #1 becomes dimmer. Bulbs #1 and #3 now have the same brightness.

D) At first the current drawn from the battery is 1 ampere so that bulb #1 is brighter than Bulb #2, but then switch #3 closes and bulb #3 illuminates. The battery current then increases to 2 amperes so that Bulbs #1, #2 and #3 are now equally bright.

E) The current drawn from the battery is 1.33 ampere until switch #3 closes and bulb #3 illuminates. The battery current then increases to 2.66 amperes; bulb #2 becomes brighter and bulb #1 becomes dimmer. Bulbs #2 and #3 are now brighter than Bulb #1.