Physics 227 – Hourly Exam 1
Thursday, October 4, 2012, 9:40 PM - 11:00 PM
ARC-103 (A-J), PLH (K-M), SEC-111 (N-R), HLL-114 (S-Z)

Your name sticker ⇒ CATW SKL
with exam code 709

SIGN HERE

1. Use a #2 pencil to make entries on the answer sheet. Enter the following ID information now, before the exam starts.
2. In the section labeled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.
3. Under STUDENT # enter your 9-digit RUID Number.
4. Under CODE enter the exam code given above.
5. Enter 227 under COURSE. You do not need to write anything else on the answer sheet for now, but you may continue to read the instructions.
6. During the exam, you are allowed one 8.5 x 11 inch sheet of paper with whatever you want written on it. NO Calculators. NO Cell phones.
7. The exam consists of 16 multiple-choice questions. For each multiple-choice question mark only one answer. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess.
8. If you have questions or problems during the exam, you may raise your hand and a proctor will assist you. If you need the value of a physical constant that is not given, we will provide it. It is your responsibility to know the relevant equations.
9. A proctor will check your name sticker and your student ID sometime during the exam. Please have them ready.
10. You are not allowed to help any other student, ask for help from anyone but a proctor, change your seat without permission from a proctor or use any electronic device. Doing so will result in a zero score for the exam.
11. When you are done with the exam, hand in only this cover sheet and your answer sheet.
12. Please sign above by the name sticker to indicate that you have read and understood these instructions.
Possibly useful constants:
\(k = 1/4\pi\epsilon_0 = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\)
\(c = \text{speed of light} = 3.00 \times 10^8 \text{ m/s}\)
\(-q_{\text{electron}} = q_{\text{proton}} = 1.602 \times 10^{-19} \text{ C}\)
\(m_{\text{electron}} = \text{electron mass} = 9.11 \times 10^{-31} \text{ kg}\)
\(m_{\text{proton}} = \text{proton mass} = 1.67 \times 10^{-27} \text{ kg}\)
Circumference of a circle = \(2\pi r\); area of a circle is \(\pi r^2\)
Surface of a sphere = \(4\pi r^2\); volume of a sphere = \(\frac{4}{3}\pi r^3\)
Surface area of a cylinder = \(2\pi rh + 2\pi r^2\); volume of cylinder = \(\pi r^2h\)
\(\sin(0^\circ) = \cos(90^\circ) = 0\)
\(\sin(90^\circ) = \cos(0^\circ) = 1\)
\(\sin(30^\circ) = \cos(60^\circ) = 1/2\)
\(\sin(60^\circ) = \cos(30^\circ) = \sqrt{3}/2\)
\(\sin(45^\circ) = \cos(45^\circ) = \sqrt{2}/2\)
\(\frac{dx^n}{dx} = nx^{n-1}\)
\(\int x^n = \frac{1}{n+1}x^{n+1}\) except when \(n = -1\). For \(n = -1\), \(\int dx/x = \ln x\)

Some metric prefixes:
f = femto = \(10^{-15}\)
p = pico = \(10^{-12}\)
n = nano = \(10^{-9}\)
\(\mu = \text{micro} = 10^{-6}\)
m = milli = \(10^{-3}\)
k = kilo = \(10^3\)
M = mega = \(10^6\)
G = giga = \(10^9\)
1. When two point charges are separated by a distance \( d \), the electric force that each one feels from the other has magnitude \( F \). In order to make this force twice as strong, the distance between the two charges would have to be changed to

\[
\frac{2}{\frac{\alpha_1}{\alpha_2^2}} = \frac{\alpha_2}{\alpha_1^2} \Rightarrow \alpha_2 = \frac{\alpha_1}{\sqrt{2}}
\]

a) \( 2d \)
b) \( \sqrt{2}d \)
c) \( \frac{d}{\sqrt{2}} \)
d) \( d/2 \)
e) \( d/4 \)

2. Two point charges, \( +q \) (on the right) and \( -q \) (on the left), are arranged as shown. Through which closed surface(s) is the net electric flux equal to zero?

- Surface A only
- Surface B only
- Surface C only
- Surface D only
- Surface C and D only

\( \Rightarrow \) No charge enclosed.

3. The figure shows a region of space with a constant electric field given by \( \vec{E} = 3\hat{x} + 2\hat{y} \) in units of \( \text{N/C} \). The dashed lines represent a sketch of the electric field. A charge \( Q = -2 \text{ C} \) is moved from a start position \((x = 0 \text{ m}, y = 0 \text{ m})\) to an end position \((x = 1 \text{ m}, y = -2 \text{ m})\). What is the change in potential energy of the charge?

\[
\begin{align*}
\Delta U &= -Q \Delta W = -Q \cdot \vec{E} \cdot \Delta \vec{x} \\
&= -(\frac{-2 \text{C}}{2 \text{C}})(3\hat{x} + 2\hat{y}) \cdot (1\hat{x} - 2\hat{y}) \left( \frac{\text{N} \cdot \text{C}}{\text{m}} \right)(\text{m}) \\
&= +2(3 - 4) = -2 \text{ J}
\end{align*}
\]
4. Each capacitor shown has a capacitance of \( C = 10 \) \( \mu \text{F} \). What is the equivalent capacitance of this combination?

\[
C_{eq} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4}
\]

(a) 10 \( \mu \text{F} \)
(b) 50 \( \mu \text{F} \)
(c) 25 \( \mu \text{F} \)
(d) 4 \( \mu \text{F} \)
(e) 2 \( \mu \text{F} \)

\[
C_{eq} = \frac{1/10 + 1/10 + 1/70 + 1/20}{\frac{1}{10} + \frac{1}{10} + \frac{1}{70} + \frac{1}{20}} = \frac{\frac{1}{10} + \frac{1}{10} + \frac{1}{70} + \frac{1}{20}}{\frac{1}{10} + \frac{1}{10} + \frac{1}{70} + \frac{1}{20}} = \frac{5}{20} \Rightarrow C_{eq} = 2 \times 4 = 8 \mu \text{F}
\]

5. Which field line configuration correctly represents an electrostatic field?

- a. B
- b. A
- c. C
- d. D
- e. E

6. At a distance \( D \) from a very long (essentially infinite) uniform line of charge, with linear charge density \( \lambda \), the electric field strength is 1000 \( \text{N/C} \). For the field strength to be 2000 \( \text{N/C} \), the distance from the line would have to be

\[
E = \frac{\lambda}{2\pi \epsilon_0 D} = 1000 \text{N/C}
\]

\[
E = 2000 \text{N/C} \quad \text{when} \quad D = \frac{D}{2}
\]

\[
E = \frac{\lambda}{2\pi \epsilon_0 (D/2)} = \frac{2(2\pi \epsilon_0 D)}{2\pi \epsilon_0 (D/2)} = 2000 \text{N/C}
\]
7. The dashed lines in the diagram represent cross sections of equipotential surfaces drawn in 1 V increments. Which of the following statements is FALSE:

a. The magnitude of the electric field at point C is greater than the magnitude of the electric field at point A. **TRUE**

b. The potential difference between A and D is 1 V. **TRUE**

c. No work \( W_{AB} \) is done by the electric force to move a 1 C charge from A to B. **TRUE**

d. No work \( W_{AD} \) is done by the electric force to move a 1 C charge from A to D. **FALSE**

e. The magnitude of the electric field at point C is greater than the magnitude of the electric field at point D. **This is also false. because of more lines proving closer D than C.**

8. There are four capacitors in the circuit shown in the figure. The capacitors are identical: \( C_1 = C_2 = C_3 = C_4 \). Initially all of the capacitors are uncharged. The switch is thrown first to position A and kept there for a long time. It is then thrown to position B. Which of the following conditions is TRUE with the switch in position B? (Note: The charges on \( C_1, C_2, C_3, \) and \( C_4 \) are \( Q_1, Q_2, Q_3 \) and \( Q_4 \) and the potential differences across them are \( V_1, V_2, V_3, \) and \( V_4, \) respectively.)

\[ \begin{align*}
\text{a)} & \quad Q_1 = Q_2 \\
\text{b)} & \quad Q_1 = 3Q_2 \\
\text{c)} & \quad V_1 = V_0 \\
\text{d)} & \quad V_1 = V_2 = V_3 = V_4 \\
\text{e)} & \quad V_1 + V_2 + V_3 + V_4 = V_0 \\
\end{align*} \]

When switch in position A, \( Q_1 = C_1 V_0 \)

When switch moved to position B (not connected to \( V_0 \),

\[ Q_1 = \left( Q_2 + Q_3 + Q_4 \right) \quad \text{but} \quad Q_2 = Q_3 = Q_4 = Q_2 \]

\[ = 3Q_2 \]
9. A charge $Q$ is placed at $x=0$ and a charge $4Q$ is placed at $+P$ on the x-axis. At what point $X$ on the x-axis between the two charges is the electric field $E$ equal to zero?

\[ E = \frac{kQ}{x^2} - \frac{k(4Q)}{(P-x)^2} = 0 \]

\[ x^2 = \frac{P}{2} - x \]

a) $X = P/2$

b) $X = P/4$

c) $X = P/5$

d) $X = P/3$

e) There is no point between the two charges where $E = 0$.

10. A hollow conducting sphere has an inner radius of 0.80 m and an outer radius of 1.20 m. The sphere carries a charge of -500 nC. A point charge of +300 nC is present at the center of the sphere. The charge on the outer surface of the conducting sphere is

a) zero

b) -300 nC

c) -500 nC

d) -800 nC

e) -200 nC

11. Two conducting spheres that carry equal charges are very far from each other and from all other charges. One of these spheres has twice the radius of the other one. If the potential of the smaller sphere (relative to infinity) is 100 V, the potential of the larger sphere (relative to infinity) is

\[ V_1 = \frac{kQ}{r} = 100V \]

\[ V_2 = \frac{kQ}{2r} = \frac{V_1}{2} = 50V \]

a) 25 V

b) 50 V

c) 100 V

d) 200 V

e) 400 V

12. A dielectric-filled parallel-plate capacitor has plate area $A$, plate separation $d$ and dielectric constant $K$. The capacitor is connected to a battery that creates a constant voltage $V$. The dielectric plate is now slowly pulled out of the capacitor, which remains connected to the battery. What is the energy $U$ stored in the capacitor at the moment when the capacitor is half-filled with the dielectric?

\[ \frac{1}{2} C_0 V^2 = \frac{1}{2} \left( C_1 + C_2 \right) V^2 = \frac{1}{2} \left( \frac{K+1}{K} \right) \frac{e_0 A}{d} V^2 \]
13. An electric dipole consists of charges $\pm 2\mu$C separated by 1 mm. It is placed in a vertical electric field of magnitude 500 N/C. The angle between the dipole moment and the electric field is 150°. The magnitude of the net torque this field exerts on the dipole is given by:

(a) $5 \times 10^{-7}$ N-m
(b) $5 \times 10^{-4}$ N-m
(c) $5\sqrt{3} \times 10^{-7}$ N-m
(d) $5\sqrt{3} \times 10^{-4}$ N-m
(e) $1 \times 10^{-6}$ N-m

14. A solid ball of an insulating material and with radius $R$ has a uniform charge density $\rho$. What is the magnitude of the electric field $E(r)$ at a distance $r < R$ from the center of the ball?

(a) $\frac{\rho r}{3\epsilon_0}$
(b) $\frac{\rho r}{\epsilon_0}$
(c) $\frac{\rho R^3}{3\epsilon_0 r^2}$
(d) $\frac{\rho R^3}{r^2 \epsilon_0}$
(e) $0$

15. Which statement(s) are TRUE for an electron moving in the direction of an electric field?

(Note: the charge on an electron $= -e = -1.6 \times 10^{-19}$ C)

I. The electron's potential energy increases as it goes from high to low potential. **TRUE**

II. The electron's potential energy decreases as it goes from high to low potential. **FALSE**

III. The electron's potential energy increases as its kinetic energy decreases. **TRUE**

IV. The electron's kinetic energy decreases as it moves in the direction of the electric field. **TRUE**

V. The electron's kinetic energy increases as it moves in the direction of the electric field. **FALSE**

(a) I and III and V only
(b) II and IV only
(c) I and V only
(d) II and V only
(e) I and III and IV only

Remember: $F_{\text{electron}} = -eE$
16. Which of the following is TRUE?

a) We can think of the energy stored in a parallel plate capacitor as being stored in the electric field between the plates. \text{TRUE}

b) Energy cannot be stored in a vacuum. \text{FALSE}

c) Electric fields require a dielectric, and do not develop in a perfect vacuum. \text{FALSE}

d) The electric field $\vec{E} = \frac{F_0}{q_0}$ measured at a point in space diverges as the test charge $q_0$ is sent to zero. \text{FALSE}

e) In general, electric field and electric potential are directly proportional to one another. \text{FALSE}