Physics 227 – First Midterm Exam  
Monday, February 25, 2019

Your name with exam code

Your signature

Turn off and put away ALL electronic devices NOW. NO cell phones, NO smart watches, NO calculators.

1. The exam will last from 5:15 to 6:10 PM.
   Use a # 2 pencil to make entries in the circles at the bottom of the cover sheet.

2. Make sure your name and RU ID are correct on the cover page. CAREFULLY detach the cover sheet (with your name, ID and the answer circles).

3. During the exam, you may use pencils, NO calculator. and ONE 8½” × 11” sheet of paper with handwritten (both sides) equations and notes.

4. There are 12 multiple-choice questions on the exam. For each question, mark only ONE and only one answer on the answer sheet. There is no subtraction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess.

No marks except filled in answer circles below the line, please.
5. Before starting the exam, make sure that your copy contains all 12 questions and the information pages. Bring your exam to the proctor if this is not the case.

6. At the end of the exam, hand in **only the cover sheet**. Retain the question sheets for future reference and study.

7. If you have questions or problems during the exam, you may raise your hand and a proctor will assist you. We will provide the value of physical constants that are needed. It is your responsibility to know the relevant equations.

8. 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.

9. **When you are done with the exam, sign the cover sheet, show your student ID to a proctor and hand in only the cover sheet.**
Possibly useful constants:

\[ \epsilon_0 = \frac{1}{\mu_0 c^2} = 8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2 \]

\[ k = \frac{1}{4\pi \epsilon_0} = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \]

\[ c = \text{speed of light} = 3.00 \times 10^8 \text{ m/s} \]

\[ -q_{\text{electron}} = q_{\text{proton}} = 1.602 \times 10^{-19} \text{ C} \]

\[ m_{\text{electron}} = \text{electron mass} = 9.11 \times 10^{-31} \text{ kg} \]

\[ m_{\text{proton}} = \text{proton mass} = 1.67 \times 10^{-27} \text{ kg} \]

\[ 1 \text{ eV} = 1.602 \times 10^{-19} \text{ J} \]

Circumference of a circle = \(2\pi r\); area of a circle is \(\pi r^2\)

Surface area 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 = \(\pi r^2h\)

\[ \sin(0^\circ) = \cos(90^\circ) = 0 \]

\[ \sin(90^\circ) = \cos(0^\circ) = 1 \]

\[ \sin(30^\circ) = \cos(60^\circ) = \frac{1}{2} \]

\[ \sin(60^\circ) = \cos(30^\circ) = \sqrt{3}/2 \]

\[ \sin(45^\circ) = \cos(45^\circ) = \sqrt{2}/2 \]

\[ \frac{dx^n}{dx} = nx^{n-1} \]

\[ \int x^n = \frac{1}{n+1}x^{n+1} \text{ except when } n = -1. \text{ For } n = -1, \int dx/x = \ln x \]

Some metric prefixes:

\[ f = \text{femto} = 10^{-15} \]

\[ p = \text{pico} = 10^{-12} \]

\[ n = \text{nano} = 10^{-9} \]

\[ \mu = \text{micro} = 10^{-6} \]

\[ m = \text{milli} = 10^{-3} \]

\[ k = \text{kilo} = 10^3 \]

\[ M = \text{mega} = 10^6 \]

\[ G = \text{giga} = 10^9 \]
1. Two point charges are placed on the x axis. Particle 1 has positive charge \(q_1\) and is located at \((+d_1, 0)\). Particle 2 has positive charge \(q_2\) and is located at \((-d_2, 0)\). What is the net electric field \(\vec{E}\) at the origin point \((0,0)\)?

   a) \(\vec{E} = + \left( \frac{kq_1}{d_1^2} \right) + \left( \frac{kq_2}{d_2^2} \right)\) in +x direction.
   
   b) \(\vec{E} = + \left( \frac{kq_1}{d_1^2} \right) - \left( \frac{kq_2}{d_2^2} \right)\) in +x direction.
   
   c) \(\vec{E} = - \left( \frac{kq_1}{d_1^2} \right) - \left( \frac{kq_2}{d_2^2} \right)\) in +x direction.
   
   d) \(\vec{E} = - \left( \frac{kq_1}{d_1^2} \right) + \left( \frac{kq_2}{d_2^2} \right)\) in +x direction.
   
   e) \(\vec{E} = + \left( \frac{kq_1}{d_1^2} \right) + \left( \frac{kq_2}{d_2^2} \right)\) in -x direction.

2. A positive charge is kept (fixed) at the center inside a fixed spherical neutral conducting shell. The positive charge is equal to roughly 16 of the smaller charges shown in the Figure on the surfaces of the spherical shell. Which picture best represents the charge distribution on the inner and outer walls of the shell?

   ![Diagram of charge distribution on the inner and outer walls of a spherical shell.]
3. The figure shows several functions of the variable \( r \). Which curve could indicate the electric potential \( V \) due to a negative charge \( q \) located at the origin \( r = 0 \)?

\[
a) \text{ Curve E } (-1/r) \text{ is the best curve to indicate the electric potential } V \text{ due to a negative charge } q. \\
b) \text{ Curve D } (-1/r^2) \text{ is the best curve to indicate the electric potential } V \text{ due to a negative charge } q. \\
c) \text{ Curve A } (1/r^2) \text{ is the best curve to indicate the electric potential } V \text{ due to a negative charge } q. \\
d) \text{ Curve C } (\ln r) \text{ is the best curve to indicate the electric potential } V \text{ due to a negative charge } q. \\
e) \text{ Curve B } (1/r) \text{ is the best curve to indicate the electric potential } V \text{ due to a negative charge } q.
\]
4. The figure displays a network of 6 identical capacitors i.e., \( C_1 = C_2 = C_3 = C_4 = C_5 = C_6 = C \). What is the equivalent capacitance \( C_{eq} \) of this network?

\[ a) \quad C_{eq} = \frac{C}{6} \]
\[ b) \quad C_{eq} = \frac{9C}{7} \]
\[ c) \quad C_{eq} = \frac{7C}{9} \]
\[ d) \quad C_{eq} = 6C \]
\[ e) \quad C_{eq} = \frac{5C}{3} \]

![Network diagram](image)

5. In the figure is a long insulating rod suspended by insulating wires. Assume that the rod is initially electrically neutral. The left end of the rod is labeled A and the right end of the rod is labeled B. A small metal ball is given a *negative* charge. The charged metal ball makes several contacts with end A of the rod. Which statement best describes how the charge on the rod is arranged?

\[ a) \quad \text{The bar remains completely neutral.} \]
\[ b) \quad \text{The bar has a positive charge on end A with end B remaining almost neutral.} \]
\[ c) \quad \text{The bar has a positive charge on end B and a negative charge on end A.} \]
\[ d) \quad \text{The bar has a negative charge on end A with end B remaining almost neutral.} \]
\[ e) \quad \text{The bar has a negative charge spread evenly on both ends.} \]

![Rod diagram](image)
6. The three small spheres show in the figure carry charges \( q_1 = +4 \, \text{nC} \), \( q_2 = -8 \, \text{nC} \), and \( q_3 = -4 \, \text{nC} \). Displayed are several closed surfaces that surround these charges. Rank the net electric flux \( \Phi \) through these surfaces.

\[ \text{a)} \quad \Phi_1 > \Phi_2 > \Phi_3 > \Phi_4 > \Phi_5 \]
\[ \text{b)} \quad \Phi_1 > \Phi_4 > \Phi_3 > \Phi_2 = \Phi_5 \]
\[ \text{c)} \quad \Phi_1 = \Phi_3 > \Phi_4 > \Phi_2 = \Phi_5 \]
\[ \text{d)} \quad \Phi_2 = \Phi_5 > \Phi_1 > \Phi_3 > \Phi_4 \]
\[ \text{e)} \quad \Phi_5 > \Phi_4 = \Phi_3 > \Phi_1 = \Phi_2 \]

7. A point charge with a charge \( q_1 \) is held stationary at the origin. A second point charge with a charge \( q_2 \) moves from point \((x_1, y_1) = (0, 0)\) to the point \((x_2, y_2)\). How much work \( W \) is done by the electric force on \( q_2 \)?

\[ \text{a)} \quad W = kq_1q_2 \left[ (1/x_1) + 1/(\sqrt{x_2^2 + y_2^2}) \right] \]
\[ \text{b)} \quad W = kq_1q_2 \left[ (1/x_1) - 1/(\sqrt{x_2^2 + y_2^2}) \right] \]
\[ \text{c)} \quad W = kq_1q_2 \left[ (1/x_1^2) - 1/(x_2^2 + y_2^2) \right] \]
\[ \text{d)} \quad W = kq_1q_2 \left[ (1/x_1^2) - 1/(y_2^2) \right] \]
\[ \text{e)} \quad W = kq_1q_2 \left[ (1/x_1^2) + 1/(y_2^2) \right] \]
8. An isolated air-filled parallel-plate capacitor, that is no longer connected to anything, has been charged up to $Q$. The separation between the plates initially is $d_1$ and with this separation the capacitance is $C$. Calculate the work $W$ that must be done to pull these isolated plates apart until their separation is tripled, i.e., $d_2 = 3d_1$.

   a) $W = \frac{Q^2}{2C}$
   b) $W = \frac{Q^2}{4C}$
   c) $W = \frac{Q^2}{3C}$
   d) $W = \frac{Q^2}{C}$
   e) $W = \frac{3Q^2}{2C'}$

9. Point charge $q_1 = -4.0 \text{ nC}$ and $q_2 = +4.0 \text{ nC}$ are separated by a distance $d = 4.0 \times 10^{-3} \text{ m}$ forming an electric dipole. The charges are in a uniform electric field whose direction makes an angle $\theta = 30^\circ$ with the line connecting the charges. What is the magnitude of this field $E$ if the torque exerted on the dipole has magnitude $\tau = 8.0 \times 10^{-9} \text{ N-m}$?

   a) $E = 1000 \text{ N/C}$
   b) $E = 500 \text{ N/C}$
   c) $E = 500(\sqrt{3}/2) \text{ N/C}$
   d) $E = 50 \text{ N/C}$
   e) $E = 100 \text{ N/C}$

10. A rectangular area is rotated in a uniform electric field from an initial position where the maximum electric flux goes through it to a final position where only half the flux goes through it. What was the angle $\theta$ of rotation? Hint: go to Possibly useful constants page for sin and cos of simple angles.

    a) $\theta = 0^\circ$
    b) $\theta = 30^\circ$
    c) $\theta = 60^\circ$
    d) $\theta = 45^\circ$
    e) $\theta = 90^\circ$
11. In the figure, three points (A, B, and C) are located on equipotential lines as shown. A negatively charged particle (e.g., electron) is released from point B. What is the direction of the electric force vector acting on this particle?

a) The electric force vector at Point B points upward.
b) The electric force vector at Point B points to the left.
c) The electric force vector at Point B points downward.
d) The electric force vector at Point B is zero.
e) The electric force vector at Point B points to the right.

12. Four parallel-plate capacitors of identical plate separation have different plate areas $A$, different capacitances $C$, and different dielectrics with dielectric constants $\kappa$.
   - Capacitor 1: $C_1 = 8$ nF, $A_1 = 2$ cm$^2$.
   - Capacitor 2: $C_2 = 8$ nF, $A_2 = 4$ cm$^2$.
   - Capacitor 3: $C_3 = 4$ nF, $A_3 = 2$ cm$^2$.
   - Capacitor 4: $C_4 = 4$ nF, $A_4 = 4$ cm$^2$.

Rank the dielectric constants $\kappa$ of the dielectrics for these four capacitors.

a) $\kappa_1 > \kappa_2 = \kappa_3 > \kappa_4$
b) $\kappa_1 > \kappa_2 > \kappa_3 > \kappa_4$
c) $\kappa_2 = \kappa_4 > \kappa_1 = \kappa_2$
d) $\kappa_3 > \kappa_1 = \kappa_2$
e) $\kappa_4 > \kappa_2 = \kappa_3 > \kappa_1$