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Instructions:

1. Don’t forget to write down your name, student ID#, and section number. You need to do this on (this page of) your test book and on your Scantron sheet as well.

2. Answer all multiple choice questions in this test book by indicating the best answer among choices. You must do this both on your test book and on your Scantron sheet. Follow instructions on the Scantron sheet on how to mark valid answers.

3. When you finish, you need to turn in both this test book and the Scantron sheet.

4: Use the blank side of question pages as additional draft spaces. An extra blank sheet is provided at the end of the test book.

5: Only one answer is allowed per problem/question. All problems have equal weight.

Constants: \( k_e = 9 \times 10^9 \text{ Nm}^2/\text{C}^2 = 1/(4\pi\varepsilon_0), \quad \varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{Nm}^2) \)

Please be very careful with the first question even though the answer will not count towards your grade:

1. ENTER THE ID CODE ABOVE IN THE UPPER RIGHT CORNER
   A. ID Code A
   B. ID Code B
   C. ID Code C
   D. ID Code D
   E. ID Code E
2. Two **negatively** charged particles, $Q_1$ and $Q_2$, are of a distance $r$ apart with $Q_2 = 2Q_1$. Compare the forces they exert on one another when $F_{21}$ is the force $Q_2$ exerts on $Q_1$ and $F_{12}$ is the force $Q_1$ exerts on $Q_2$. Which of the followings is true?

A. $2F_{21} = -F_{12}$
B. $F_{21} = -2F_{12}$
C. $F_{21} = 2F_{12}$
D. $F_{21} = -F_{12}$

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C. $F_{21} = 2F_{12}$
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3. Three point charges, all have $Q = 50 \mu C$, are placed on the $x$ axis at $x=-1.0$ m, 0.0 m, and +1.0 m, respectively. What is the magnitude of the electrostatic force on the charge at $x = +1.0$ m?

A. 2.0 N
B. 4.5 N
C. 6.5 N
D. None of above

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4. A sphere of $r=1.0$ m has a charge of $60 \mu C$ at its center. What is the total electric flux through its surface?

A. $3.2 \times 10^6$ Nm$^2$/C
B. $4.5 \times 10^6$ Nm$^2$/C
C. $6.8 \times 10^6$ Nm$^2$/C
D. $9.8 \times 10^6$ Nm$^2$/C

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D. $9.8 \times 10^6$ Nm$^2$/C

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5. In the previous setting, if a second point charge of $Q=60 \mu C$ is now added at a position which is 0.5 m from the first charge which is at the center of the same sphere, what is the total electric flux through the surface of the sphere?

A. same as before
B. twice as much
C. 4 times as much
D. none of above

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A. same as before
B. twice as much
C. 4 times as much
D. none of above
6. A point charge of \( Q = -50 \mu C \), initially rests at position A inside an electrostatic field, is being moved and put rest at a new position B in the field. During the process, work done by the external force that moves the charge is 2.0 mJ. The distance between point A and B is 10 cm. What is the potential difference between point A and B, \( V_B - V_A \)?

A. 40 V  
B. -40 V  
C. -400 V  
D. can not determine as the electric field strength is not given.

\[ \Delta KE = 0 \quad (KE=\text{kinetic energy}) \]
\[ W = (U_f - U_i) + \Delta KE = (U_B - U_A) = Q(V_B - V_A) \]
\[ \rightarrow V_B - V_A = W/Q = -40V \]

7. A circular ring of radius \( R=2.0m \) has a charge \( Q=2.0 \mu C \) uniformly distributed along it. A test charge \( q=1.0 \mu C \) is placed at the center of the ring. What is the magnitude of the force on the test charge?

A. 0  
B. 2.25 mN  
C. 4.5 mN  
D. 9.0 mN

\[ F=0, \text{ per argument of symmetry} \]

8. Three concentric thin \textbf{conductive} spherical shells A,B,C, have radius \( r_A=R, r_B=2R, \) and \( r_C=4R \) and charges \( Q_A=Q, Q_B=-Q, \) and \( Q_C=3Q, \) respectively. (\( Q>0 \)). Rank the electric potentials of the shells.

\[ \text{Per argument of symmetry and per Gauss's Law:} \]
\[ \cdot \text{ Between sphere A and B, electric field points outwards,} \]
\[ \rightarrow \text{lower V as } r \text{ increases } \ V_A>V_B \]
\[ \cdot \text{ Between sphere B and C, E=0} \]
\[ \rightarrow \text{ Same potential } V_B=V_C \]

A. \( V_A>V_B>V_C \)  
B. \( V_A<V_B<V_C \)  
C. \( V_A=V_B>V_C \)  
D. \( V_A>V_B=V_C \)
9. Three point charges of $Q = 6 \times 10^{-5} \text{C}$ each are initially far apart from each other. What is the minimum energy required to put them, respectively, at the corners of an equilateral triangle of side length 1.0m?

A. $32.4 \text{ J}$  
B. $43.4 \text{ J}$  
C. $97.2 \text{ J}$  
D. $114.6 \text{ J}$

\[ \Delta U = U_f - U_i \]  
\[ U_i = 0 \]  
\[ U_f = 3k_e Q^2/r = 97.2 \text{ J} \]

10. As shown in figure below, a conducting spherical shell, of inner radius $R$ and outer radius $2R$, carries a total charge $-2Q$ ($Q > 0$). A point charge $+Q$ is placed at the center of the shell. Concentric to the conducting shell is an insulating spherical shell of radius $3R$ with negligible thickness. A charge of $+Q$ is uniformly distributed on this insulating shell.

What is the magnitude of electric field at $r=2.5R$.

A. $k_e Q/(2.5R)^2$  
B. $k_e 2Q/(2.5R)^2$  
C. $k_e 3Q/(2.5R)^2$  
D. zero

Per Gauss’s Law and per symmetry, one can get $E = k_e q_{\text{encl}}/r^2$.
For $2R < r < 3R$, $q_{\text{encl}} = -Q \rightarrow E = -k_e Q/(2.5R)^2$ (take magnitude only)

11. In the above setting, let the electric potential be zero at infinity, what is the potential at $r=3.5R$?

A. $k_e Q/(3.5R)$  
B. $k_e 2Q/(3.5R)$  
C. $-k_e 2Q/(3.5R)$  
D. zero

Per Gauss’s Law and per symmetry, one can get $E = k_e q_{\text{encl}}/r^2$.
For $r > 3R$, $q_{\text{encl}} = 0 \rightarrow E = 0 \rightarrow$ Same V as infinity
12. In figure above, the surface charge at point A, which is on the surface of the conductor at -10 V, is
   A. positive
   B. negative
   C. zero
   D. can not be determined

   See fig above, first draw electric field line, noting that they shall always point to lower potential. Then use argument that electric field always pointing away from positive charges.

13. In the figure above, a test charge q of charge 1.0μC is placed at point C, the magnitude of the electric force on q is
   A. +1.0μN
   B. -1.0μN
   C. zero
   D. can not be determined

   Without distance information, Electric field strength can not be determined by potential alone

14. In the above figure, a test charge q of charge 1.0μC is moved from point C to point A. Ignoring the effect of the test charge q on the field, what is the work done to q by the electric field in the process?
   A. 2.0 μJ
   B. -2.0 μJ
   C. zero
   D. none of above or can not be determined.

   \[ W_{\text{electric field}} = -(U_f-U_i) = -q(V_f-V_i) = -2\mu J \]

   Review Phy201 if in question of the – sign.
15. The electric potential distribution of an electric field is described by expression 

\[ V = 2x^2 + 5xy - 7xz. \]

What is the magnitude of the force on a test charge of 1.0 \( \mu \)C at location \((x,y,z) = (1.0, 1.0,1.0)\)? (SI units implied).

A. 7.5 \( \mu \)N  
B. 8.8 \( \mu \)N  
C. 11.9 \( \mu \)N  
D. 17.6 \( \mu \)N  

\[ E_x = -dV/dx = -4x-5y+7z, \quad E_y = -5x, \quad E_z = 7x \]

\[ F = qE = q \sqrt{E_x^2 + E_y^2 + E_z^2} = 8.8 \mu \text{N at (1,1,1)} \]

16. The electric potential distribution of an electric field is described by expression 

\[ V = 2x^2 + 5xy - 7xz. \]

A test charge of 1.0\( \mu \)C is moved from \((x,y,z) = (1.0, 1.0,1.0)\) to \((1.0,2.0,1.0)\), then to \((1.0,2.0,3.0)\), and then to \((2.0, 2.0,3.0)\) and finally to \((2.0,1.0,2.0)\). What is the total work done by the field to the test charge in the whole process? (SI units implied).

A. 10.0 \( \mu \)J  
B. -10.0 \( \mu \)J  
C. -5.0 \( \mu \)J  
D. +5.0 \( \mu \)J  

\[ W = -(U_f - U_i) = q(V_f - V_i) \]

\[ V_f = V(2,1,2) = -10 \text{V}, \quad V_i = V(1,1,1) = 0 \text{V} \]

\[ \Rightarrow W = 10.0 \mu \text{J} \]

17. Three capacitors, \( C_1 = 2 \mu \text{F}, \quad C_2 = 4 \mu \text{F} \) and \( C_3 = 6 \mu \text{F} \) are connected as shown in fig A:

![Fig A](image1.png)  

The combined capacitance of capacitors in Fig A is:

A. 7.3 \( \mu \)F  
B. 12 \( \mu \)F  
C. 3 \( \mu \)F  
D. None of above  

\[ C_{12} = C_1 + C_2 = 6 \mu \text{F} \]

\[ C_{123} = 1/(1/C_{12} + 1/C_3) = 3 \mu \text{F} \]
18. In above Fig A, how much is the charge on C1?
A. 12 μC
B. 24 μC
C. 18 μC
D. None of above

19. Still in the above Fig A, what is the total energy stored in the three capacitors?
A. 216 μJ
B. 526 μJ
C. 10368 μJ
D. none of above

20. Still in the above Fig A, what is the ratio of the energy stored in C1 to that in C2? (ie. U1:U2)
A. 4:1
B. 1:4
C. 2:1
D. 1:2

21. Now some dielectric material is filled in between plates of C1 (which has original capacitance of 2 μF), as shown in fig B above. The dielectric material has a dielectric constant κ=2. What is the ratio of the energy stored in C1 to that in C2
A. 8:1
B. 1:8
C. 2:1
D. none of above