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PHYSICS DEPARTMENT

PHY 2049 Exam 1 February 3, 2010

Name (print, last first): ______________________ Signature: ______________________

On my honor, I have neither given nor received unauthorized aid on this examination.

YOUR TEST NUMBER IS THE 5-DIGIT NUMBER AT THE TOP OF EACH PAGE.

DIRECTIONS

(1) **Code your test number on your answer sheet (use 76–80 for the 5-digit number)**. Code your name on your answer sheet. **DARKEN CIRCLES COMPLETELY**. Code your student number on your answer sheet.
(2) Print your name on this sheet and sign it also.
(3) Do all scratch work anywhere on this exam that you like. At the end of the test, this exam printout is to be turned in. No credit will be given without both answer sheet and printout with scratch work most questions demand.
(4) **Blacken the circle of your intended answer completely, using a #2 pencil or blue or black ink**. Do not make any stray marks or the answer sheet may not read properly.
(5) The answers are rounded off. Choose the closest to exact. There is no penalty for guessing.

>>>>>>>>**WHEN YOU FINISH** <<<<<<<<
Hand in the answer sheet separately.

Constants: $e = 1.6 \times 10^{-19}$ C $\quad m_p = 1.67 \times 10^{-27}$ kg $\quad m_e = 9.1 \times 10^{-31} kg \quad g = 9.8 m/s^2 \quad$ micro $= 10^{-6}$

$\epsilon_o = 8.85 \times 10^{-12} C^2/N \cdot m^2 \quad k = 1/(4\pi\epsilon_o) = 9 \times 10^9\, N \cdot m^2/C^2 \quad \mu_o = 4\pi \times 10^{-7} T \cdot m/A \quad$ nano $= 10^{-9}$ pico $= 10^{-12}$

Coulomb's Law: $|\vec{F}| = \dfrac{|q_1||q_2|}{4\pi\epsilon_o r^2}$ (point charge)

Electric field: $\vec{E} = \dfrac{\vec{F}}{q} \qquad \vec{E} = \dfrac{q}{4\pi\epsilon_o r^2}\hat{r}$ (point charge) $\qquad \vec{E} = \int \dfrac{dq}{4\pi\epsilon_o r^2}\hat{r}$ (general) $\qquad E = \dfrac{\sigma}{2\epsilon_o}$ (plane)

Gauss' law: $\Phi = \hat{n} \cdot \vec{E}\, A = \oint \hat{n} \cdot \vec{E}\, dA = \dfrac{q_{enc}}{\epsilon_o}$

Energy: $W = \int \vec{F} \cdot d\vec{s} = \dfrac{1}{2} m v_f^2 - \dfrac{1}{2} m v_i^2 = K_f - K_i \qquad P = \vec{F} \cdot \vec{v}$ (mechanical power)

For conservative forces $U_f - U_i = -\int \vec{F} \cdot d\vec{s} \rightarrow K_i + U_i = K_f + U_f$

Electric potential: $V = \dfrac{U}{q} \qquad V = \dfrac{q}{4\pi\epsilon_o r}$ (point charge) $\qquad V = \int \dfrac{dq}{4\pi\epsilon_o r}$ (general)

$V_b - V_a = -\int_a^b E_x dx = -\int_a^b \vec{E} \cdot d\vec{s} \qquad E_x = -\dfrac{\partial V}{\partial x}, \qquad E_y = -\dfrac{\partial V}{\partial y}, \qquad E_z = -\dfrac{\partial V}{\partial z}$

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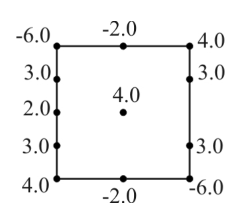
1. A spherical conducting drop of water carrying a charge of 25 pC has a potential of 380 V at its surface relative to infinity. If three water droplets with the same charge and radius merge, what is the potential at the surface of the new droplet?

(1) 550 V (2) 380 V (3) 1140 V (4) 790 V (5) 660 V

2. A long solid copper cylinder has radius 1 cm and length of 90 cm. The field at the surface of the cylinder is 9000 N/C going outwards. What is the charge on the cylinder?

(1) 0 nC (2) 2.2 nC (3) 0.05 nC (4) 4.5 nC (5) 0.11 nc

3. In the figure, the central particle of charge 4.0 nC is surrounded by the square array of charged particles (also in units of nC). The square has side length of 1 mm. The magnitude of the net force on the central particle due to the others is (Hint: if you don't use symmetry to greatly reduce the work of solving this problem come back to it last).



(1) 1.23 N (2) 0.58 N (3) 1.06 N (4) 0.29 N (5) 0.88 N

 21111

4. A proton located at $x = 1$ m is released along the positive x direction in a electric potential of the form $V(x) = 5 - 3/x$, where x is measured in meters and V is measured in volts. What minimum initial velocity is needed for the proton to be able to reach infinity?

(1) 3.1×10^4 m/s (2) 6.7×10^5 m/s (3) Not possible (4) 2.4×10^4 m/s (5) 3.9×10^5 m/s

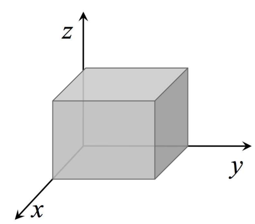
5. Refer to the previous problem. What is the x component of the force acting on the proton at $x = 3$?

(1) -5.3×10^{-20} N (2) $+1.8 \times 10^{-19}$ N (3) $+3.3 \times 10^{-20}$ N (4) -1.8×10^{-19} N (5) $+5.3 \times 10^{-20}$ N

6. Two point particles, with charges of q_1 and q_2, are placed a distance r apart. The electric field is zero at a point P between the particles on the line segment connecting them. We conclude that:

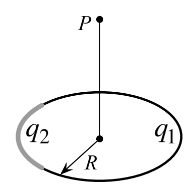
(1) q_1 and q_2 must have the same sign but may have different magnitudes.
(2) q_1 and q_2 must have the same magnitude and sign.
(3) q_1 and q_2 must have equal magnitudes and opposite signs.
(4) q_1 and q_2 must have opposite signs and may have different magnitudes.
(5) P must be midway between the particles.

7. A non-uniform electric field given by $\vec{E} = 5.5\hat{\imath} - 2.1\hat{\jmath} + (4.6z^2 - 3)\hat{k}$ N/C pierces a cube with sides 3 m, as shown in the figure. The cube has its rear corner at the origin. What is the total charge inside the cube?



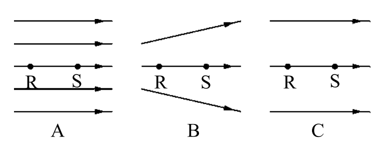
(1) +2.8 nC
(2) +3.3 nC
(3) +0.37 nC
(4) −2.4 nC
(5) −5.2 nC

8. A plastic rod has been bent into a circle of radius $R = 5.5$ cm. It has a charge $q_1 = +4.2$ pC uniformly distributed along three-quarter of its circumference and a charge $q_2 = -4q_1$ uniformly distributed along the rest of the circumference (see figure). Assuming $V = 0$ at infinity, what is the electric potential in volts at point P, which is on the central axis of the circle at distance $D = 6.5$ cm from the center?



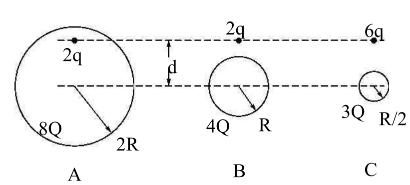
(1) +8.7 (2) +54 (3) −2.43 (4) −1.33 (5) +0.54

9. The figure shows the electric field lines in three different regions of space. The points labeled R and S are the same distance apart in each region. A proton is let go from rest at point R in each region. Rank order the proton momentum on reaching S for the three cases.



(1) $A > B > C$ (2) $C > B > A$ (3) $A > C > B$ (4) $B > C > A$ (5) $B > A > C$

10. The figure shows 3 insulating hollow spheres that have the indicated charge (aQ) uniformly distributed on their surfaces. In each case there is a point particle of the indicated charge (bq) a distance d from the center of the hollow sphere. Rank order the electrostatic force between the sphere and the point charge for the three cases.



(1) $C > A > B$ (2) $A > B > C$ (3) $A > C > B$ (4) $B = C > A$ (5) $C > B > A$

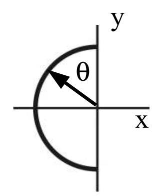
11. An electron traveling along the x axis (toward increasing x) has a speed of 4.0×10^6 m/s. At time $t = 0$ it enters a region of space in which there is an electric field of 10.0 N/C$\hat{j}$. At a time $t = 10\mu$s later the electron's velocity makes an angle with respect to the +x axis that is:

(1) much less than 1° (2) +36° (3) +77° (4) −36° (5) −77°

12. Two isolated conducting spheres are separated by a large distance. Sphere 1 has a radius of R and an initial charge $3Q$ while sphere 2 has a radius of $3R$ and an initial charge $7Q$. A very thin copper wire is now connected to the spheres. Charge flows between the spheres until they reach the same electrical potential. How much charge will be transferred from sphere 2 to sphere 1? (Note that the charge transferred can be positive, negative or zero .)

(1) $-Q/2$ (2) $+2Q$ (3) $+4Q$ (4) $-2Q$ (5) 0

13. A semi-circular, thin, insulating rod with a total charge of +80.0 nC uniformly distributed along its length, has a radius of 10 cm. If we needed to express an infinitesimal element of charge on the rod, dq, in terms of the infinitesimal angular variable $d\theta$ measured in radians, such that $dq = ud\theta$, (as we would if we wanted to determine the electric field at the origin, see figure) then for this case u is:



(1) 500 nC/radian (2) 80 nC/radian (3) 25 nC/radian (4) 50 nC/radian (5) 250 nC/radian

14. Two identical conducting spheres A and B carry identical charges. They are separated by a distance much larger than their diameters. The magnitude of the electrostatic force between the spheres is F. A third, identical conducting sphere is first touched to earth ground and then touched to sphere A and moved away. The magnitude of the electrostatic force between spheres A and B is now:

(1) $\frac{1}{4}F$ (2) indeterminate from the information given (3) 0 (4) $\frac{1}{2}F$ (5) $2F$

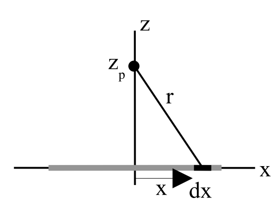
15. Suppose we have an insulating spherical ball of uniform charge density ρ and radius R. At what radius or radii from the center of the sphere is the electric field strength reduced by a factor of 16 from the electric field strength at the surface?

(1) $R/16$ and $4R$ (2) $R/64$ and $4R$ (3) Only at $R/4$ (4) Only at $4R$ (5) $R/4$ and $4R$

16. An electric dipole centered at the origin of a Cartesian coordinate system is oriented so that the line between the two charges lies along the z axis with the positive charge on the $+z$ side of the origin. The direction of the force experienced by a charge $+q$ that lies on the x axis at a distance far from the origin is:

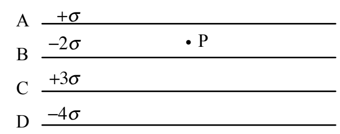
(1) $-\hat{k}$ (2) $-\hat{\imath}$ (3) $\hat{k}$ (4) $\hat{k}$ (5) It depends on the distance.

17. In the figure the gray rod has uniform linear charge density λ. The **z component** of the infinitesimal electric field at point z_p due to the infinitesimal element of charge contained in the infinitesimal line element dx can be written $dE_z =$



(1) $k\frac{z_p\lambda dx}{(x^2+z_p^2)^{1/3}}$ (2) $k\frac{\lambda dx}{(x^2+z_p^2)^{3/2}}$ (3) $k\frac{z_p\lambda dx}{(x^2+z_p^2)^2}$ (4) $k\frac{z_p\lambda dx}{(x^2+z_p^2)^{3/2}}$ (5) $k\frac{z_p\lambda dx}{(x^2+z_p^2)^{1/2}}$

18. Four parallel infinite sheets of charge spaced by 4 cm between adjacent sheets are shown edgewise in the figure. Their surface charge densities are as indicated with $\sigma = 2.0\mu\text{C/m}^2$. What is the magnitude of the electric field (in N/C) at point P located midway between two sheets as shown? (Hint: Electric fields are vectors that add as such.)



(1) 9.0×10^5 (2) 4.5×10^5 (3) 0 (4) 1.13×10^5 (5) 2.3×10^5

19. Members of a space mission discover a mysterious alien artifact consisting of a solid conducting sphere of radius 4 cm floating inside a conducting shell with inner and outer radii 10 cm and 12 cm, respectively. Scientists measure the electric field strength at different places, obtaining $E = 4500$ N/C pointing inward at $r = 7$ cm and $E = 7600$ N/C pointing outward at $r = 15$ cm. What is the total charge on the outer shell?

(1) +19.0 nC (2) +21.5 nC (3) +16.6 nC (4) −25.4 nC (5) −2.45 nC

20. A line of charge extending along the x axis has a continuous charge density given by $\lambda = (5x)$ nC/m. How much charge is contained on the line from $x = 2$ to $x = 4$ meters?

(1) 40 nC (2) 22 nC (3) 30 nC (4) 6 nC (5) 8 nC